3. FINDINGS

This section of the report summarizes the key findings from the WSDOT Statewide Communications Plan development effort. These findings include information collected during several different tasks, as well as the results of numerous interviews, team meetings, report reviews and site visits. Many of the Network Architecture diagrams were obtained from the WSDOT Office of Information Technology (OIT) and are reprinted with permission.

Through the course of the interviews and meetings, it became apparent that there are a number of different ways in which information flows and the associated communications requirements for video, voice or data may be categorized. Five main categories of information flows and communications requirements have been defined for this report, as follows:

- **Inter-regional Communications**: Office-to-Office Data and Video information flows and communications requirements between WSDOT Regions or between a Region and State HQ. These information flows include Enterprise or Administrative functions, as well as those required to support ITS initiatives.

- **Intra-regional Communications**: Office-to-Office Data and Video information flows and communications requirements within a given WSDOT Region. These information flows include Enterprise or Administrative functions, as well as those required to support ITS initiatives. They may also include information flows with other agencies, such as local municipalities, city TMCs, Emergency Response agencies, etc.

- **Phone/PBX Network**: Basic voice phone service for WSDOT offices, whether used primarily for internal WSDOT 4-digit dialing or long distance dialing. This system supports a video conferencing system available at a small handful of offices.

- **Center-to-Field Voice Communications**: Includes person-to-person and dispatch-to-field communications, and includes both vehicle mounted radios and hand-held mobile radios. The network that supports these communications includes both a backbone microwave network and a distribution radio network, which are defined in more detail later in this section.

- **Center-to-Field Data and Video Communications**: Includes center-to-vehicle and center-to-field devices, along with video and data requirements, which primarily support ITS initiatives.

In addition to these five categories of information flows, a sixth category was added:

- **Policy Issues**: Includes issues that impact either communications needs or subsequent specific recommendations.

3.1 INTER-REGIONAL COMMUNICATIONS

The bulk of WSDOT's inter-regional communications and information flows tend to be between regional offices and WSDOT Headquarters, with minimal region-to-region communications. This seems to be the case for both administrative/enterprise communications and ITS communications, including voice, video and data.

The remainder of this subsection (and subsequent subsections) discusses the following elements:

- **Existing Infrastructure and Architecture**: Describes existing inter-regional owned or leased infrastructure, bandwidth size and network architecture.
- **Traffic**: Types of traffic on the network, including discussion on voice, video, data, and specific applications.
- **Utilization**: Levels of utilization of the existing network.
- **Planned Upgrades**: Discussion of any known upgrades to the above infrastructure that are already planned or underway. Occasionally, bandwidth connections differ when compared to those shown in the network diagrams from WSDOT OIT. These have been discussed under planned upgrades, although in some cases they may have already been upgraded.
- **Growth**: Qualitative discussion of potential growth of network utilization, based on current trends and other issues identified during the data gathering tasks.

3.1.1 Existing Infrastructure and Architecture

Figure 2 illustrates the Network Architecture of sites fed directly from the Olympia Headquarters (referred to in the diagram as Olympia Service Center or OSC). The majority of these connections are leased line connections—except for the fiber connections indicated in the figure— and the majority of the leased lines are either point-to-point T1 or Frame Relay T1 circuits (shared between multiple sites). In addition, there is a T-3 ATM Circuit between the Olympia HQ and Northwest Region HQ (indicated as Dayton HQ in Figure 2).

Six of the sites fed directly from Olympia Headquarters (Oly HQ) are the WSDOT Regional Headquarters buildings. The site indicated as "2911 Building" is one of the primary Washington State Ferries (WSF) facilities (the other primary WSF facilities are connected to 2911 via fiber). This segment indicates the connection between WSDOT Oly HQ and WSF. For the purposes of this report, these seven sites (identified in Figure 2), and their associated connections to Oly HQ, have been defined as the key inter-regional Communications Connections.

Figure 3 illustrates these seven key inter-regional connections geographically. This figure is an output from the Geographic Information System (GIS) database developed specifically for this project.

Each one of these connections is leased (at varying monthly rates) from one of several private telecommunications service providers. The service provider generally offers some sort of Level-of-Service guarantee, which usually covers bandwidth availability, maximum downtimes and repair procedures.

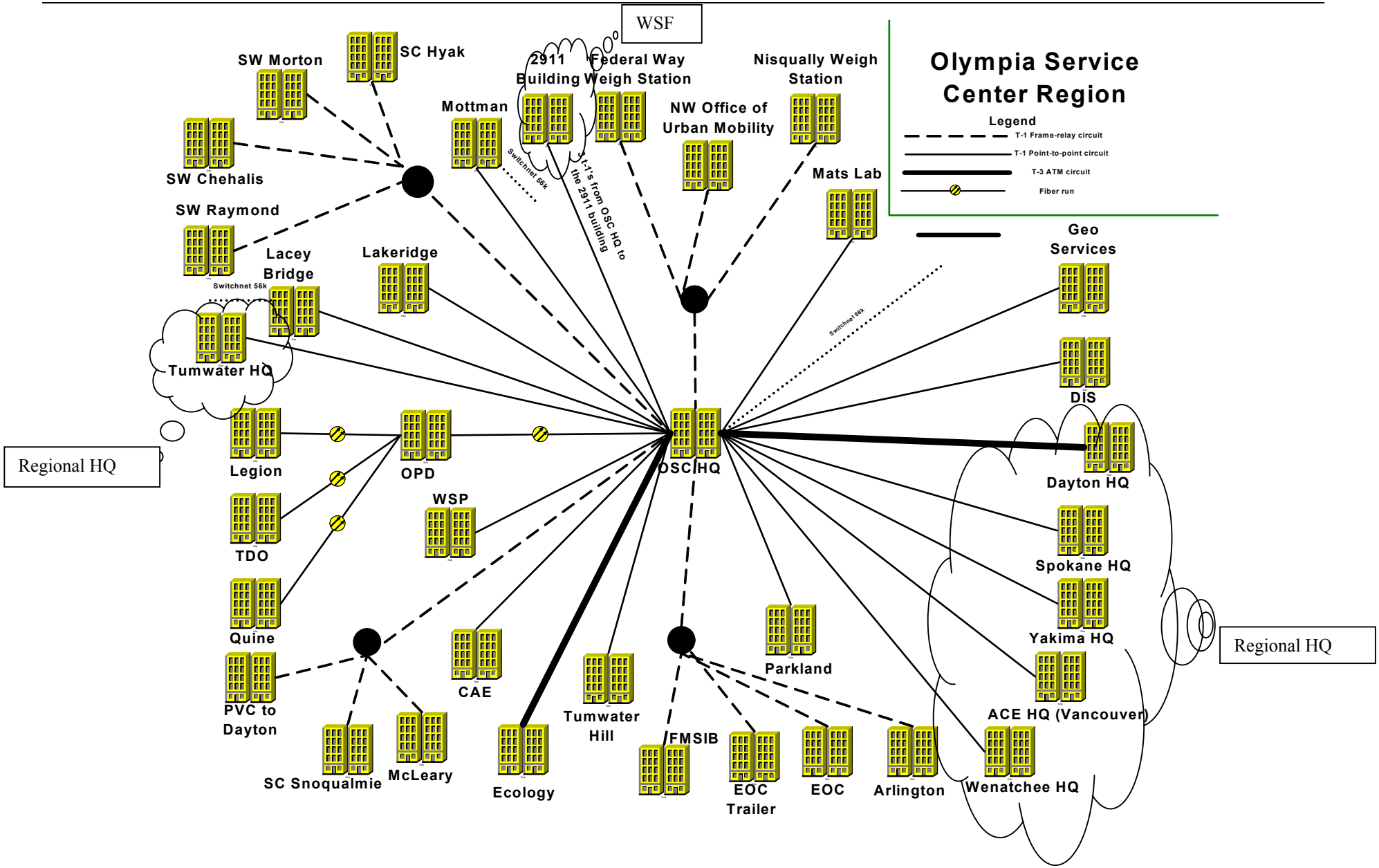


Figure 2: WSDOT Sites fed from Olympia Headquarters

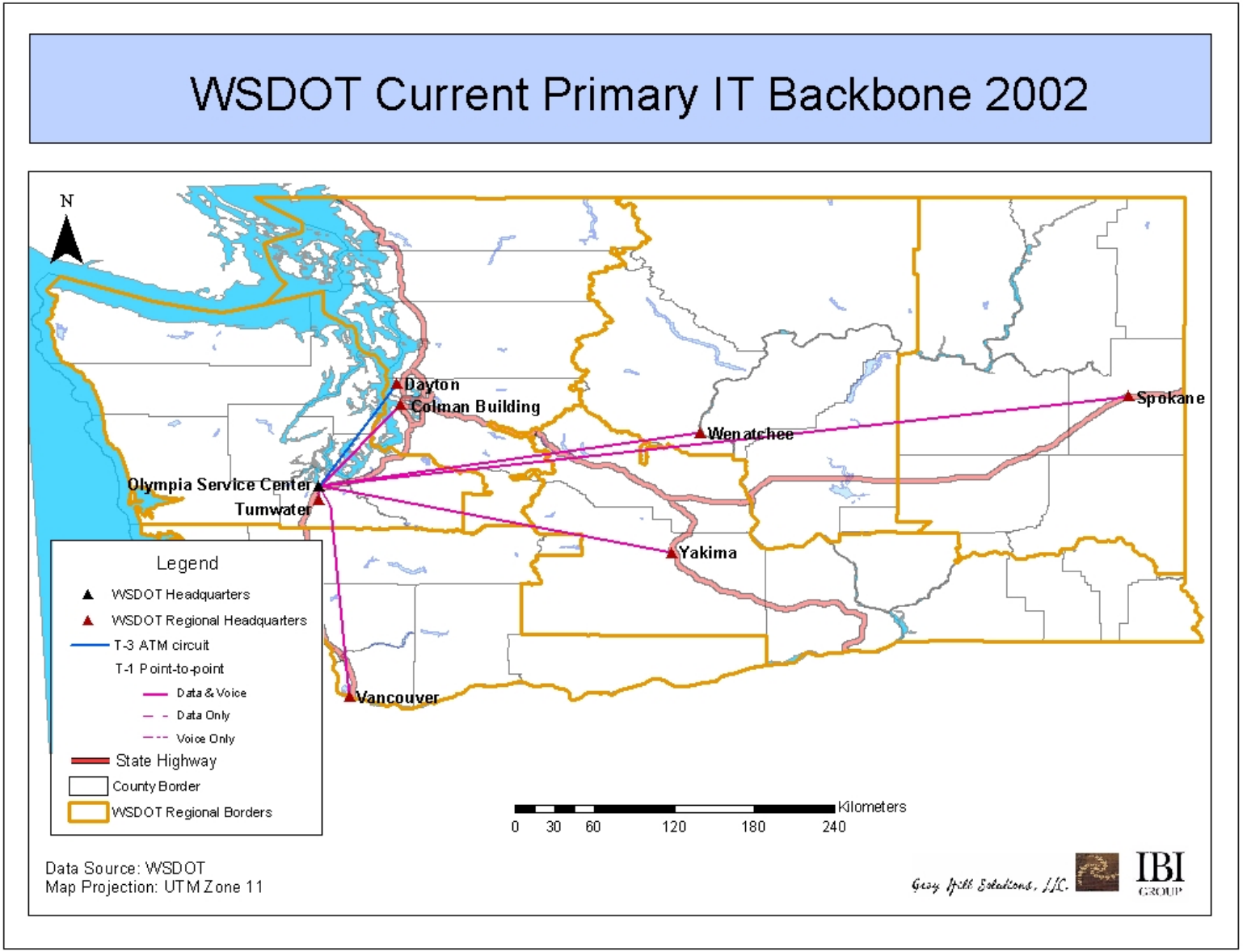


Figure 3: WSDOT Primary Inter-regional Leased Lines

3.1.2 Communications Traffic

3.1.2.1 Enterprise/IT

This network of inter-regional leased lines is used for voice, video and data communications. In regards to voice communications, the phone network utilizes these leased lines. This network is discussed in more detail under the Phone/PBX section below. These links are also used to create the WSDOT WAN, which allows the regional offices access to email and the Internet, as well as to the WSDOT Intranet. WSDOT Intranet applications include SRview, AutoCAD, and Microstation.

Due to the fact that WSDOT utilizes a star topology, these inter-regional connections are heavily utilized. Under the star topology, all of the regional data or video traffic that is to go through the Internet, either from the region to Olympia or between regions, utilizes these inter-regional connections. Figure 4 illustrates this point, by showing a generic region with field offices, a TMC and Regional Headquarters, and the star topology connecting these offices back to the Olympia Headquarters and then out to a different Regional Headquarters.

3.1.2.2 ITS

These same inter-regional leased line connections are used for ITS video and data traffic as well. Probably the most significant application (from the bandwidth perspective) is the posting of video images from the CCTV cameras located in each region to the Internet. Each of these video images are sent from the camera in the field, to the local TMC (whether in full motion, snap shot or reduced frame motion.) From the regional TMC, the images are sent as snapshot images[2] to the Internet using the regional HQ to Olympia HQ connections.

In addition to the video images, significant amounts of data are sent from the regional ITS devices through the regional TMCs and on to Olympia for data storage, as well as for a number of applications. Some of these applications include:

- **Traffic Flow Maps:** Using data from traffic detectors
- **Pass Conditions:** Using data from Road Weather Information Systems (RWIS)
- **Roadside Device Status:** Current message and status of Highway Advisory Radios (HAR) and Variable Message Signs (VMS) deployed across the state. Plans are underway for the statewide networking of HAR, which would facilitate the recording and updating of messages.
- **Commercial Vehicle Operations (CVO):** CVO data includes permit status and data collected at weigh stations. With the increasing need to monitor and track freight for both security and operational reasons, CVO-related data is likely to increase.

[2] The Northwest Region has begun posting small video clips on-line in addition to snapshot video. These video clips require additional bandwidth.

- **Condition Acquisition and Reporting System (CARS):** Incident data entered into the CARS system by TMC and maintenance staff, is accessible to authorized users across the state. CARS will be linked with the Washington State Patrol's CAD system.

Currently, there is little region-to-region coordination/control of ITS devices. The primary exceptions are:

- **Hyak Pass**: North Central region operates the majority of the devices and Northwest region operates the remainder (with some cross over) and;

- **Between North Central and South Central:** Since North Central region does not have a true TMC, South Central acts as the TMC for both regions, and controls all of North Central's devices during off hours.

It is likely that the current extent of region-to-region ITS coordination/control may increase as more devices are deployed along regional boundaries, and as more opportunities for cooperation between regions develop. This is discussed below in Section 3.1.5 on Growth.

At this time, WSDOT is seriously considering the development of a Statewide Traffic Operations Center/Emergency Operations Center (STOC/EOC) to be located in the vicinity of Olympia Headquarters. The purpose of the STOC/EOC would be to consolidate and integrate statewide traffic monitoring, device control, and information dissemination. The potential functions of the STOC/EOC and the likely associated growth of network traffic are discussed in more detail in Section 3.1.5.

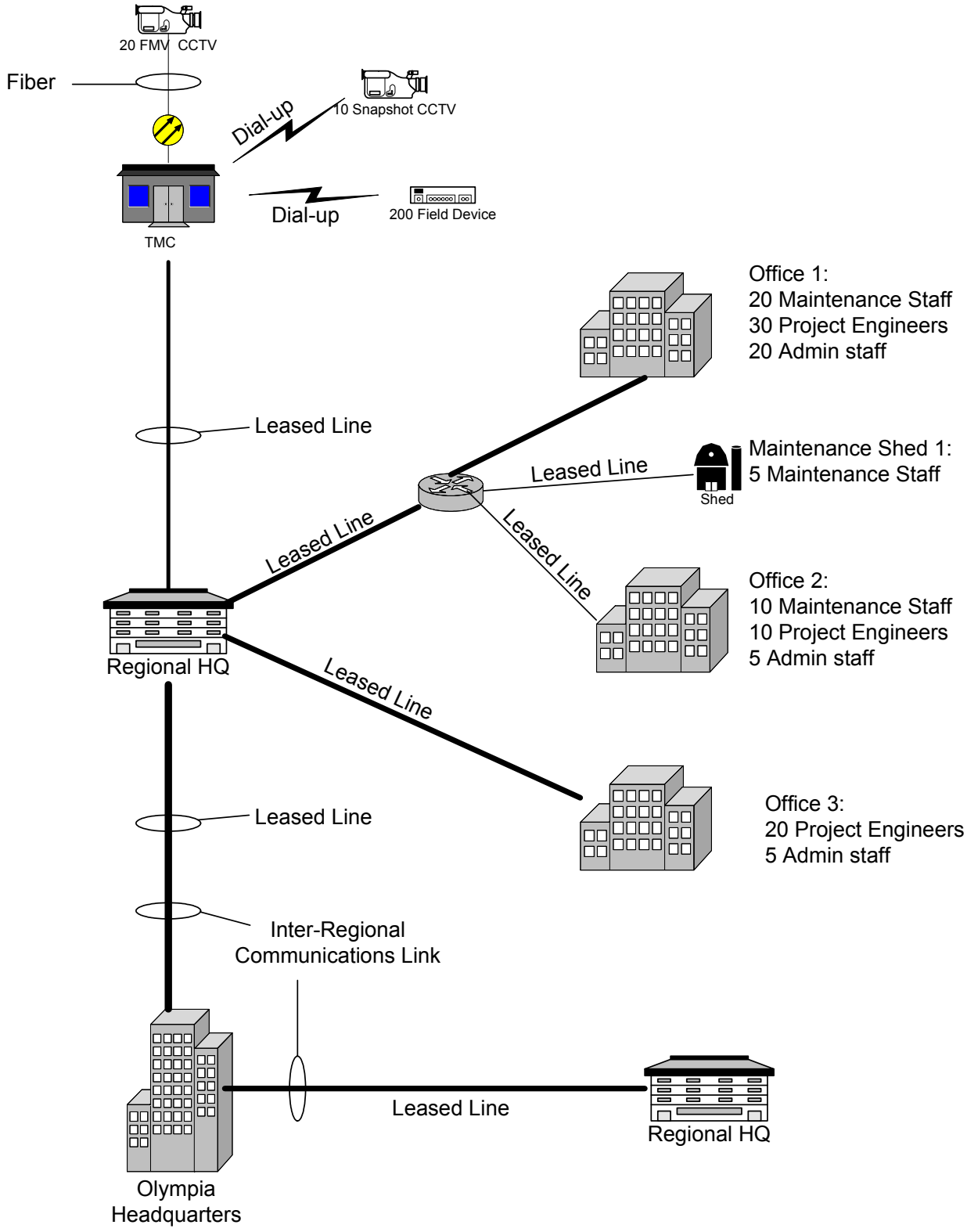


Figure 4: Example Star Topology from Region to Olympia HQ

3.1.3 Utilization

WSDOT's Office of Information Technology (OIT) does an excellent job of monitoring the utilization of all WSDOT data links, by remotely polling utilization records from the routers. Using this data, OIT develops bandwidth utilization charts to illustrate network usage, identify potential "choke points" (or heavy utilization segments) and proactively manage the network.

Figure 5 is an example of a bandwidth utilization chart from WSDOT OIT. This chart is displaying the average daily usage of the point-to-point T1 link between the Yakima Regional HQ and Olympia HQ offices for the month of October 2002.

At the top of the chart is the link identification tag (name of the segment). This tag identifies the routers on each end of the link. Directly below the tag is the bandwidth size indicator (note 1.544 Mbs indicates a full T1.) The chart itself shows time (in days) as the horizontal (-x) axis and bandwidth utilization as a percentage of the full 1.544 Mbs as the vertical (-y) axis. The average utilization for each day is shown.

As bandwidth utilization increases, the number of data collisions or bit errors increases accordingly, creating network slowdowns and occasionally, lost data. The following are some very general rules of thumb for bandwidth utilization:

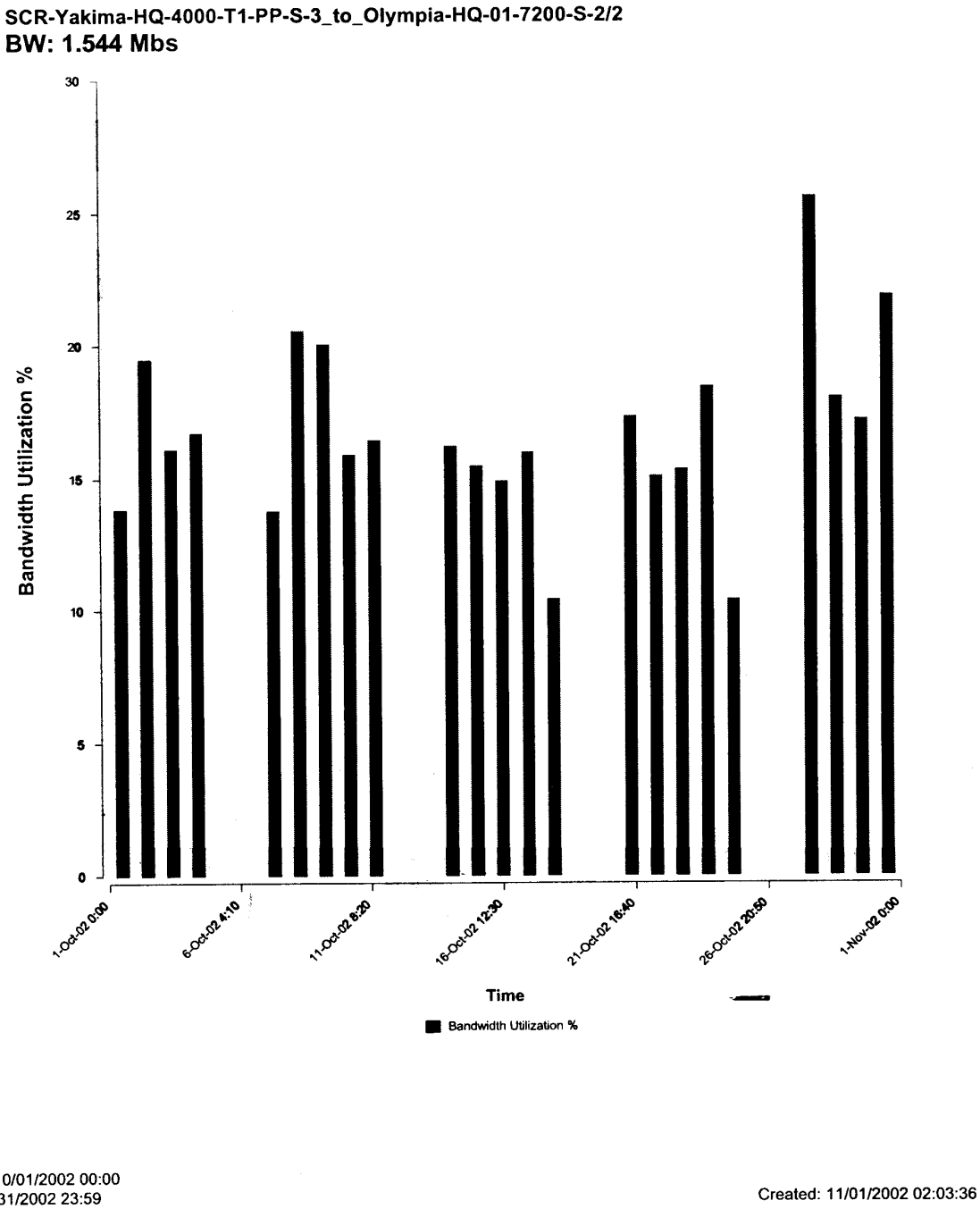
- **Less than 20% Utilization**: Should not experience notable system slowdown.
- **20-30% Utilization**: Will start noticing periodic system slowdown and may consider upgrading link bandwidth or other action[3] to reduce utilization percentage.
- **Greater than 30% Utilization**: Will likely notice regular system slowdown and occasional lost data; should consider upgrading link bandwidth or other action to reduce utilization percentage.

Figure 6 is a chart indicating the bandwidth utilization of all of the Inter-regional Leased Line Connections, again using data from the month of October 2002. The chart shows the range of daily utilization levels that were observed throughout the month. As can be seen, only the Wenatchee HQ to Olympia HQ segment currently exceed the 20% utilization "barrier"; but the Tumwater HQ, Spokane HQ and Yakima HQ are all very close to this threshold and will likely exceed it in the near future.

[3] "Other action" may include implementing an alternate or redundant route, utilizing a different technology such as fiber or wireless communications, or changing the topology of the network.

South Central Region Trend Report

Normal Work Hours Only



From: 10/01/2002 00:00
To: 10/31/2002 23:59

Created: 11/01/2002 02:03:36

Figure 5: Example Bandwidth Utilization Chart

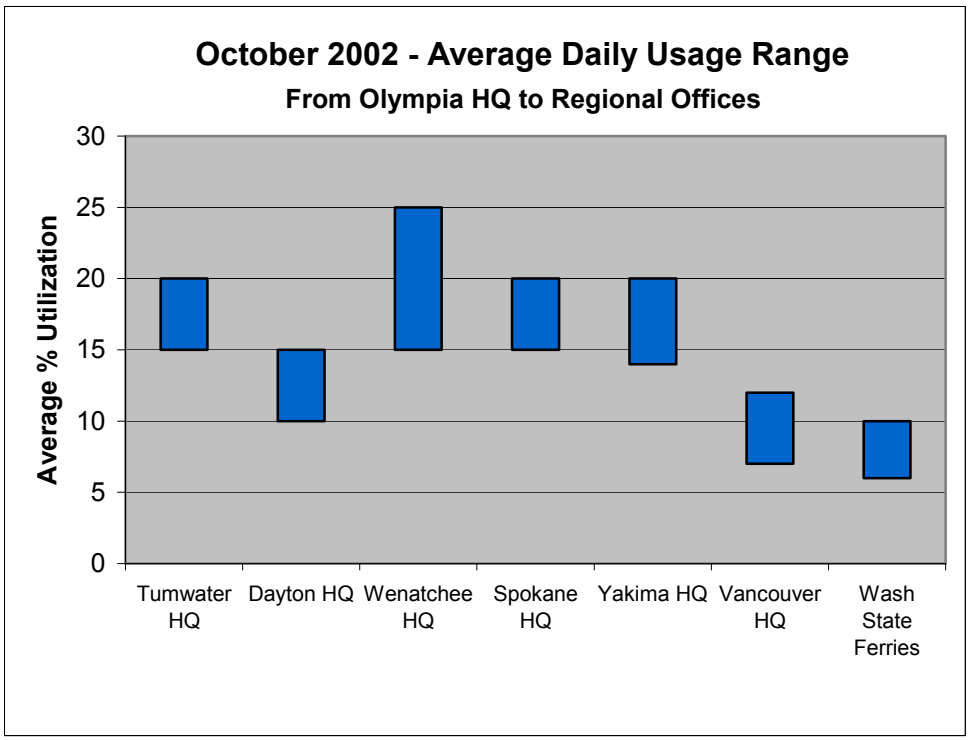


Figure 6: Bandwidth Utilization of Inter-regional Connections

3.1.4 Planned Upgrades

As discussed above, some of the Leased Line segments were identified during the interviews to have a different total available bandwidth than the segments identified in Figure 2[4]. The interviews indicated that upgrades are planned for the following two segments and it is possible these upgrades may already have taken place:

- **Tumwater HQ to Olympia HQ**: The planned upgrade is for two T1s for data and a third T1 for voice communications. If the upgrade is already in place, this may account for why this connection is currently below the 20% utilization threshold.

- **Vancouver HQ to Olympia HQ (Leased Line):** The planned upgrade is for two T1s on this link. As above, the presence of a second T1 (if already in place) may account for why this connection is currently well below the 20% utilization threshold.

- **Vancouver HQ to Olympia HQ (Microwave):** In addition to the two leased-line T1s, there is a third T1 between Vancouver and Olympia that is utilizing the WSDOT/WSP jointly-owned microwave network. At the time of the interviews, this link was in "test

[4] Note: WSDOT OIT updates these Network Architecture schematics regularly. Some of these upgrades may have already been identified in recent updates.

mode" but has since been migrated to a fully operational data link. This will be discussed in more detail in subsequent sections.

- **Quest 100Mbs Upgrade:** Subsequent to the interviews, WSDOT has continued to pursue opportunities to upgrade several leased line communications links. Through continued negotiations with Qwest, WSDOT is planning on upgrading links between WSDOT HQ in Olympia, Dayton (NW Region HQ and TMC), Ecology, CAE, the Materials Lab, Olympic Region HQ and the Tacoma TMC all to dedicated 100Mbs connections.

- **NoaNet 100 Mbs Upgrade:** Subsequent to the interviews, WSDOT has continued to pursue opportunities to upgrade several other leased line communications links. Through negotiations with NoaNet, WSDOT is planning on upgrading links between WSDOT HQ in Olympia, Wenatchee (NC Reg. HQ), Spokane (Eastern Reg. HQ), Yakima (SC Reg. HQ), Vancouver (SW Reg. HQ) and the WSF HQ all to a shared 100Mbs ring (through Portland, OR) on the NoaNet backbone.

See Figure 7 for a schematic illustration of the planned Qwest and NoaNet upgrades described above. These upgrades will be able to support improved data connections, provide higher quality video conferencing service, add phone lines (through packetized T1s for PBX links) and allow continued deployment of Voice over IP for phone service. It is envisioned that WSDOT will have increased focus on utilizing video conferencing to minimize travel costs, particularly once these upgrades are in place.

These new routes will bring additional redundancy (both carrier and physical entry into the building) into the WSDOT HQ building.

Completion of these upgrades is also contingent on finding "last mile" solutions in each of the markets. In many cases, this is the responsibility of the telecommunications provider, however, in some markets (including City of Seattle, City of Spokane and City of Vancouver) local municipalities of constructed their own fiber networks. In each of these areas, negotiations are underway with local municipalities to determine if they may be able to provide an acceptable and more cost effective last mile solution.

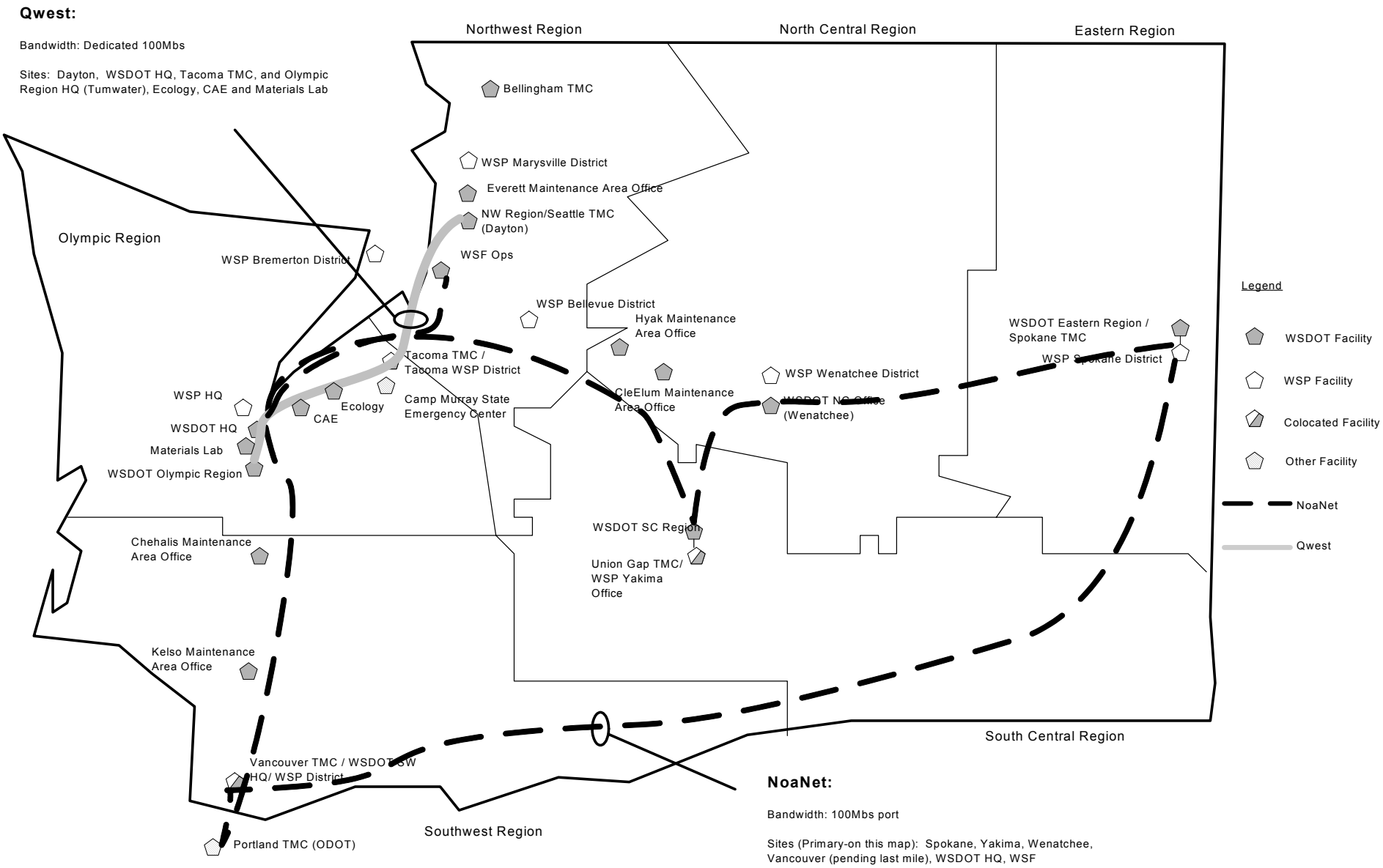


Figure 7: Planned Qwest and NoaNet 100Mbs Upgrades

3.1.5 Growth

3.1.5.1 Enterprise/IT

As a general rule, bandwidth requirements of nearly any enterprise tend to increase over time, assuming other factors stay relatively constant (number of employees, offices, etc.). This is due to a number of factors – including issues such as increasing numbers of people becoming familiar with, using, and even becoming dependent on, the use of email and the Internet. There is also generally increasing use of other on-line internal and external applications, and many organizations are developing (and encouraging the use of) their own on-line applications, such as time sheets and reports.

It is important to note that because Referendum 51 failed to pass, WSDOT is projecting the need for some significant staff reductions under the current law budget. While it is impossible to predict the exact impact on communications requirements at this point, it is likely that there will be an associated leveling off (or even a short-term reduction) in network utilization and associated bandwidth requirements. However, it is anticipated that this shorter-term reduction in usage will at some point be outweighed by the normal increases in network utilization and the issues discussed below.

The network upgrades discussed above are expected to significantly improve the operation of the video conferencing system. Subsequently, it is anticipated that use of the video conferencing system is expected to grow, particularly in the impacted offices.

There are a number of specific trends at WSDOT that will continue to drive bandwidth requirements up, in addition to the general increase discussed above. The following are some examples (not all-inclusive) of driving forces that will likely increase bandwidth requirements:

3.1.5.1.1 Centralization of Applications

There has been an increasing trend at WSDOT towards the centralization of applications. The current Secretary of Transportation, Doug MacDonald (who took office in Spring of 2001), has placed an increased emphasis on performance measuring throughout the agency. The Secretary's office produces the quarterly performance measure report: *Measures, Markers and Mileposts* (known informally as "The Gray Notebook"). In order to efficiently collect the data required for this and other reporting mechanisms, more and more applications are being developed by WSDOT, whereby field personnel can prepare reports on-line while the application itself is running from a centrally located server (either at the regional HQ or at Olympia HQ). Maintenance, Operations, Inventory, Engineering, Administration, and Incident Response are some of the departments that are currently, or soon will be, utilizing these applications.

As each new application becomes centralized, it puts an increased strain on the network segments between the individual using the application and the server where the application is housed. This strain is particularly great when larger-size files are attached or included in the application, such as CAD drawings, digital photos, SR View images, etc.

This trend towards centralization of applications appears likely to continue and is supported at all levels.

3.1.5.1.2 "Big Bandwidth" Applications

There are a number of "big bandwidth" applications being used by WSDOT, most notably SRview, which runs on the WSDOT intranet. SRview allows the user access to digital images of Washington's highway system in increments of 1/100 of a mile. WSDOT has developed SRweb for external use, whereby the information and images available in SRview are available to outside users via the Internet and browser software. The most notable difference between SRweb and SRview is that SRweb requires manual advances to view the images.

SRview runs over the network, therefore whoever is accessing SRview images is actually accessing them from the server where they are located, whether that be at a regional office or at Olympia HQ. All of the network segments between the user and the server are then impacted. A large volume of digital information is transferred, so the application requires "big bandwidth" between the server and user to function.

In addition to SRview, there are a number of design and engineering applications which can be heavy bandwidth users, including CAICE, Microstation CAD, GIS, and aerial photography, just to name a few. Design techniques are becoming increasingly complex and often designers are layering images from one application on top of another. For example, a designer might start with an aerial photograph, overlay a CAD drawing, and then overlay GIS data. This impacts network utilization in two ways. First, when users access data from an online server, they are utilizing network links between that user and the server. Second, once the design drawings are completed, they are often sent via email to several other colleagues or external entities. Emailing such large files impacts the network as well.

3.1.5.1.3 Digitizing of Construction Documents

One of the other trends that was discussed during the interviews was the possible decision to digitize and store all construction documentation, including construction drawings, contracts, submittals (as applicable), change orders, RFIs, correspondence, etc. This would include any new major construction project (which admittedly will be minimal for the foreseeable future with the failure of Referendum 51), but also any maintenance projects which require construction documentation (which will continue). This directive may also be somewhat retroactive with construction projects that have already been completed.

The uploading of such construction documents from the field to file servers located at Olympia HQ would have some bandwidth implications. It is not clear at this point if a policy will be implemented to ensure that such files are only downloaded in off peak periods. Also, what is not clear at this point is if and how these documents are intended to be accessed in the future. For example, if the intent is for them to be called up and viewed remotely, additional bandwidth impacts may continue beyond the initial upload.

3.1.5.2 ITS

The growth in ITS bandwidth requirements is more directly related to the number of devices deployed in the field, how often they are polled and the way that they are utilized. As discussed, video is often the largest user of available bandwidth. The CCTV camera images have proven to be very effective for incident verification and management and are very popular traveler information sources (via the Internet). This program is likely to continue to grow, with additional cameras being deployed throughout the state. This will impact inter-regional communications requirements in a number of ways:

- **Increased number of images**: To be backhauled from the device, to the regional TMC and on to Olympia to be posted on the web,

- **Increased desire for inter-regional coordination**: As CCTV cameras are deployed near regional boundaries, neighboring regional TMCs may want to have viewing and possibly control capabilities of each other's cameras. In addition to CCTV cameras, neighboring regions predict a growing desire to have access to (and in some cases control of) HAR and VMS messaging in neighboring regions.

- **Possible usage of full motion video**: The Northwest region's display of video clips (in addition to still images), is in response to what many system users have requested, i.e., better information. Full motion video (or even limited video clips) gives the user a better sense of true traffic flow conditions. However, it also has extremely significant impacts on bandwidth utilization. If the trend continues towards providing more full motion video, bandwidth impacts will need to be looked at closely.

As discussed previously, in addition to video images, there are significant volumes of data being sent to Olympia for field device data storage, application, and even for posting on the Internet. Again, as more devices are deployed, bandwidth requirements will increase. Additionally, some new applications may require more frequent polling of device data. Whenever this is the case, bandwidth impacts will be felt.

Finally, the biggest potential ITS development that could have serious inter-regional bandwidth implications is the proposed Statewide Traffic Operations Center/Emergency Operations Center (STOC/EOC). Appendix A includes a brief description of the proposed STOC/EOC, including Possible Functions, Operations Scenarios, Center Layout and Space Requirements. To summarize this Appendix, the possible functions of the STOC/EOC include:

- **Monitoring Existing Web and Media Information**: Requiring the STOC/EOC to have access to all of the information currently available on WSDOT's website, as well as access to other information providers, such as the media, statewide.

- **Integration of Other Data Sources**: Some data sources, such as the TDO data stations and CVO transponders and tags, are not currently being used for operations or travel time data. To make use of these, special applications, and links to the field devices will have to be developed.

- **Statewide Monitoring and Management of HAR, VMS and CCTV**: Statewide monitoring of HAR may be an extension of the statewide HAR network project (currently underway), while potential statewide monitoring of VMS and CCTV would be an entirely new endeavor.

- **Emergency Response Operations**: the STOC/EOC could become the new WSDOT HQ Emergency Operations Center (EOC) and would be the location where WSDOT coordinated with other agencies, local municipalities, WSP, etc, in times of significant events with a large geographic impact.

While the functions and applications of the proposed STOC/EOC are still in the very preliminary planning stages at this point, it is apparent that any STOC/EOC could have significant bandwidth requirements from linking each of the regional TMCs back to Olympia HQ, as well as to other emergency providers such as WSP.

3.2 INTRA-REGIONAL COMMUNICATIONS

Intra-regional communications include the various video, voice and data connections between facilities located within a given WSDOT region. This includes WSDOT office-to-office communications, as well as communications with any other agency, including WSP, local municipalities, emergency service providers, etc.

3.2.1 Existing Infrastructure and Architecture

3.2.1.1 Leased Line

Figure 8 through Figure 14 are the Network Architecture diagrams provided by WSDOT OIT for each of the six WSDOT regions and WSF. As with the inter-regional connections, these include point-to-point T1s and frame relay T1s, however, there are also segments of fiber build between several offices and 56K dial-up at several of the smaller offices (generally maintenance sheds.) Often times, one or more of the sites in the Frame Relay "cluster" are much larger than the other sites or at least have higher bandwidth requirements, due to the nature of the facility. If one of the sites in the "cluster" is such a high bandwidth user that it causes a network slowdown, the other sites will experience the slowdown as well. The purpose of identifying the individual high bandwidth segment is to indicate which leased line segments would bring the biggest benefit if upgraded or replaced by either microwave or fiber connections.

The overall architecture is a star configuration, where the majority of offices have a connection to the Regional HQ. There are a small number of offices that link to the Regional HQ through another office. Voice and data traffic between the local office and Olympia HQ travels over the intra-regional communication network to the Regional HQ and then over the inter-regional network to Olympia. Communications traffic between regions from a local office also follows this path to Olympia, where it is routed to the destination in another region. Figure 15 illustrates the same intra-regional connections in geographic format, using the Eastern Region as an example. Again, this map was generated from the GIS database developed specifically for this project. The data is available in this database to generate similar maps for each region as required

by WSDOT. The entire statewide network (including all sites within each region) has been mapped and included as an attachment to this report.

Again, each of these T1 or 56K connections is leased at varying monthly rates from a private telecommunications service provider. The fiber is owned and maintained by WSDOT.

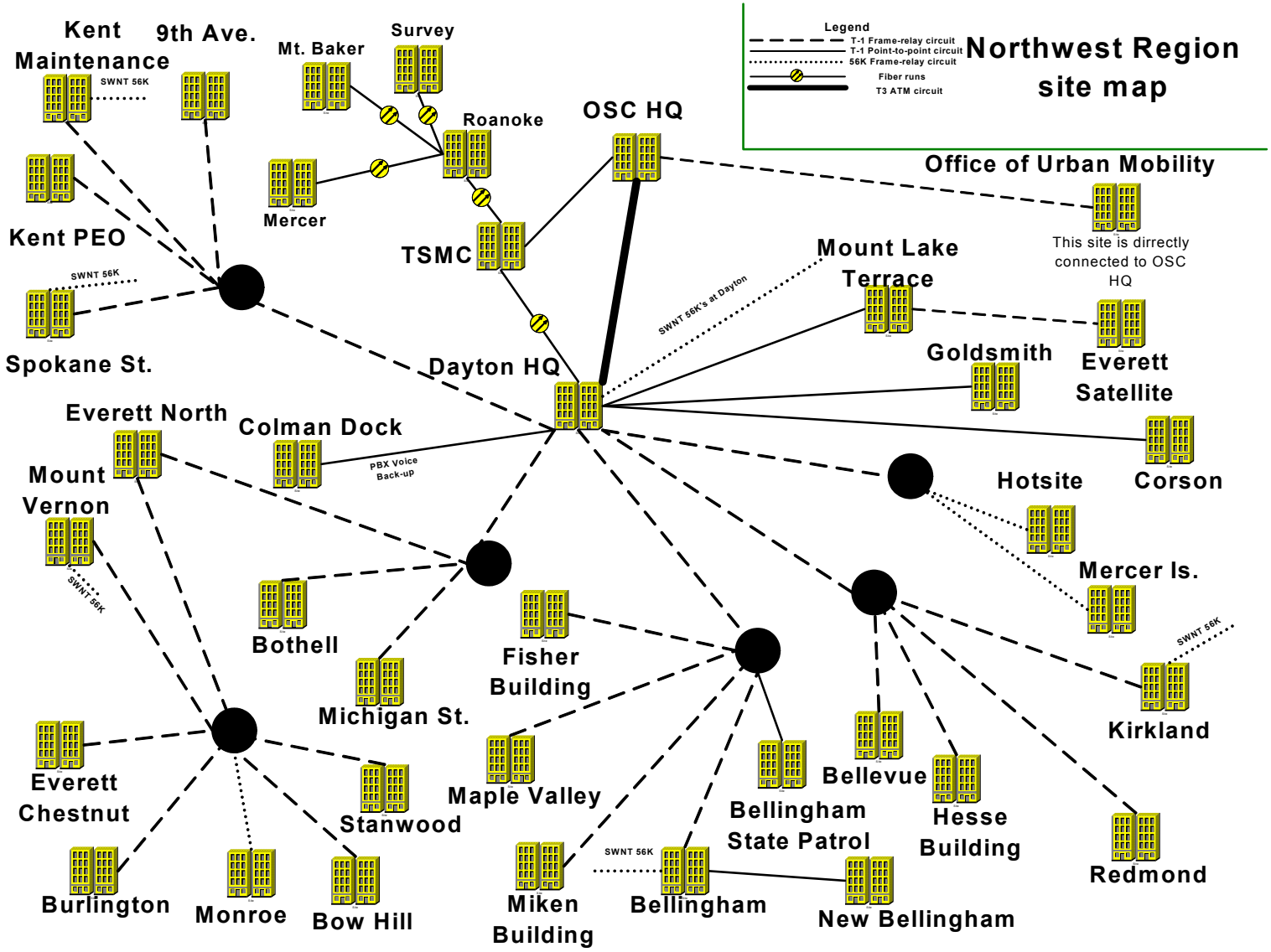


Figure 8: Northwest Region Leased Line Network

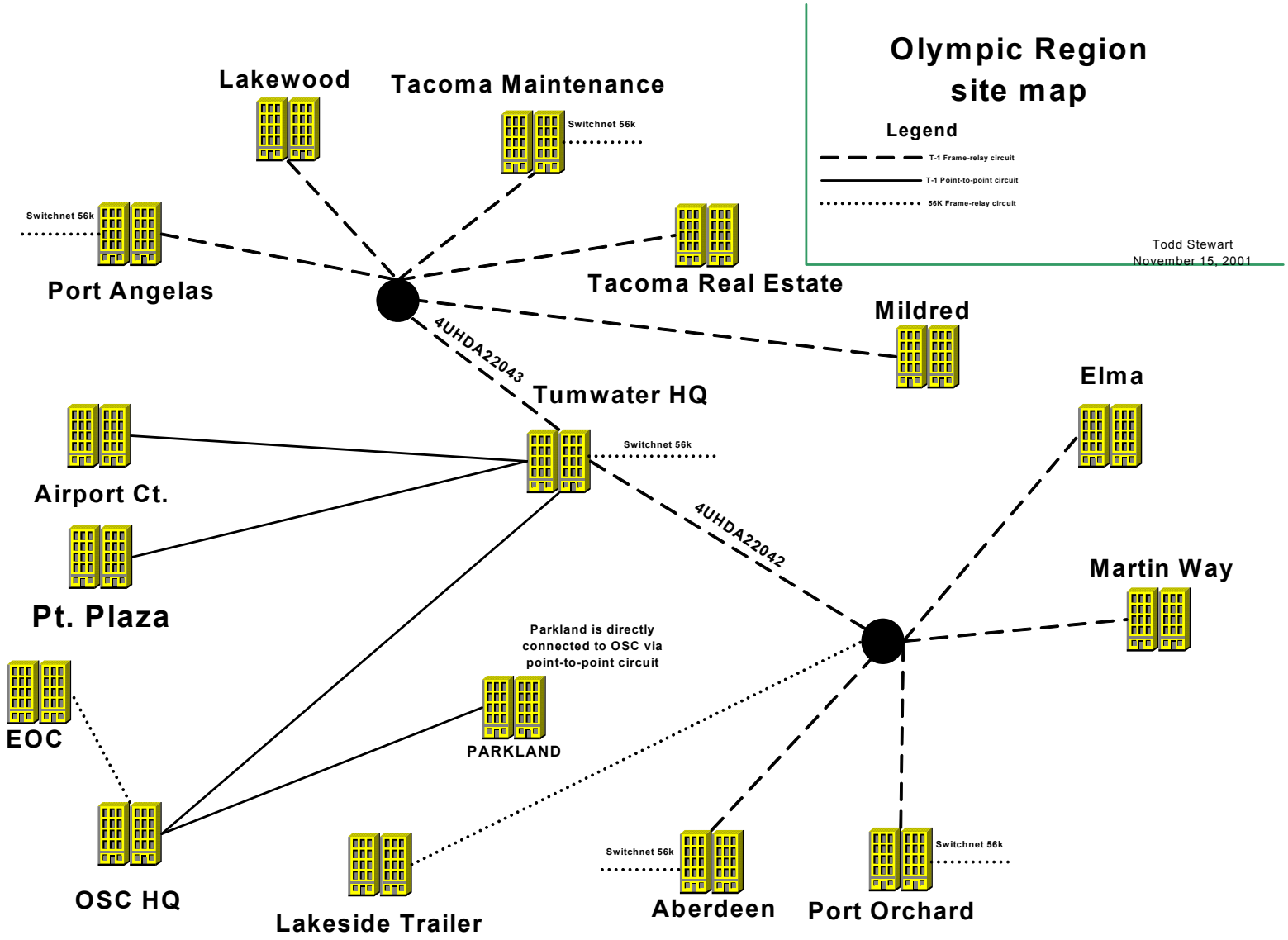


Figure 9: Olympic Region Leased Line Network

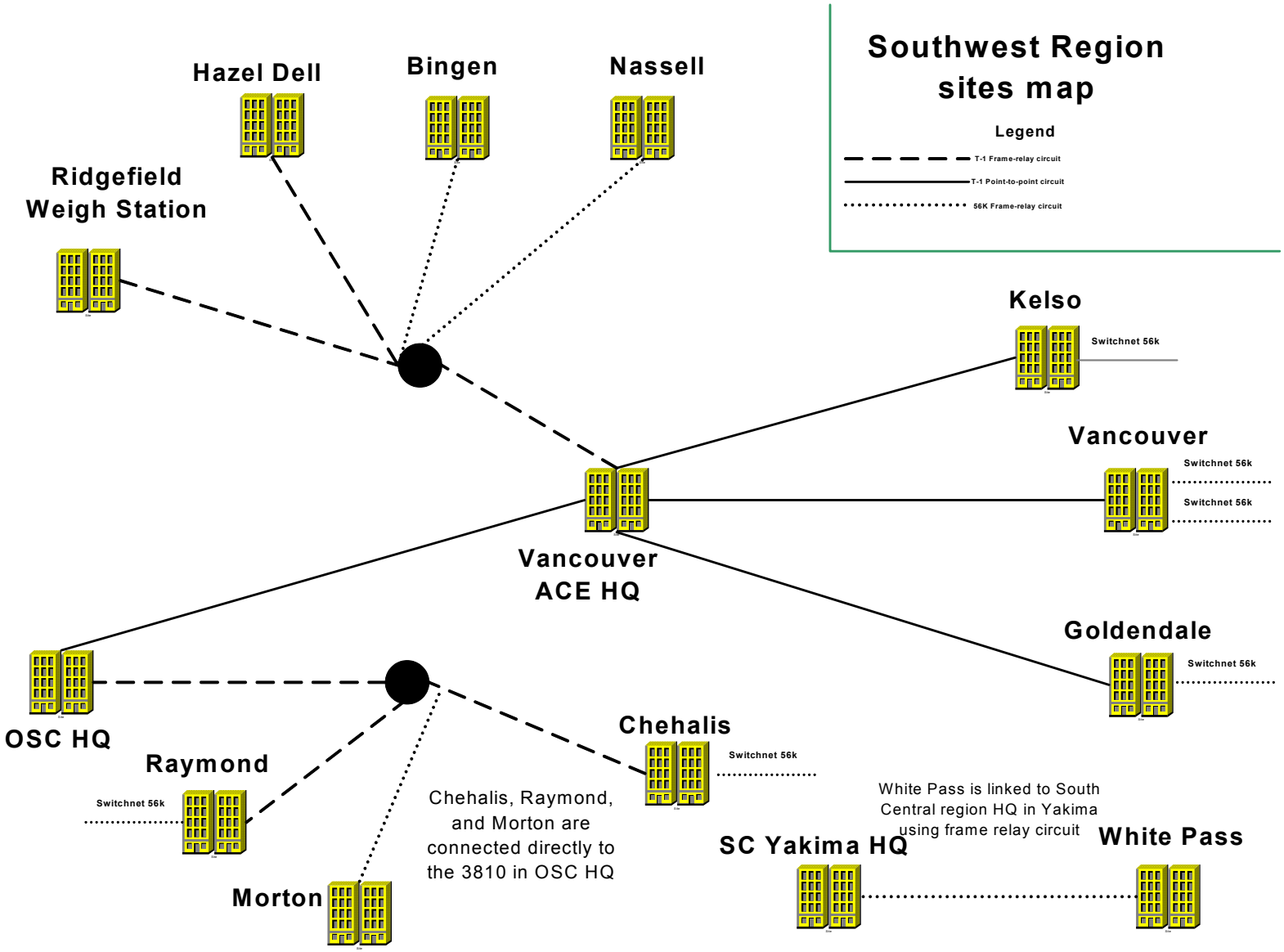


Figure 10: Southwest Region Leased Line Network

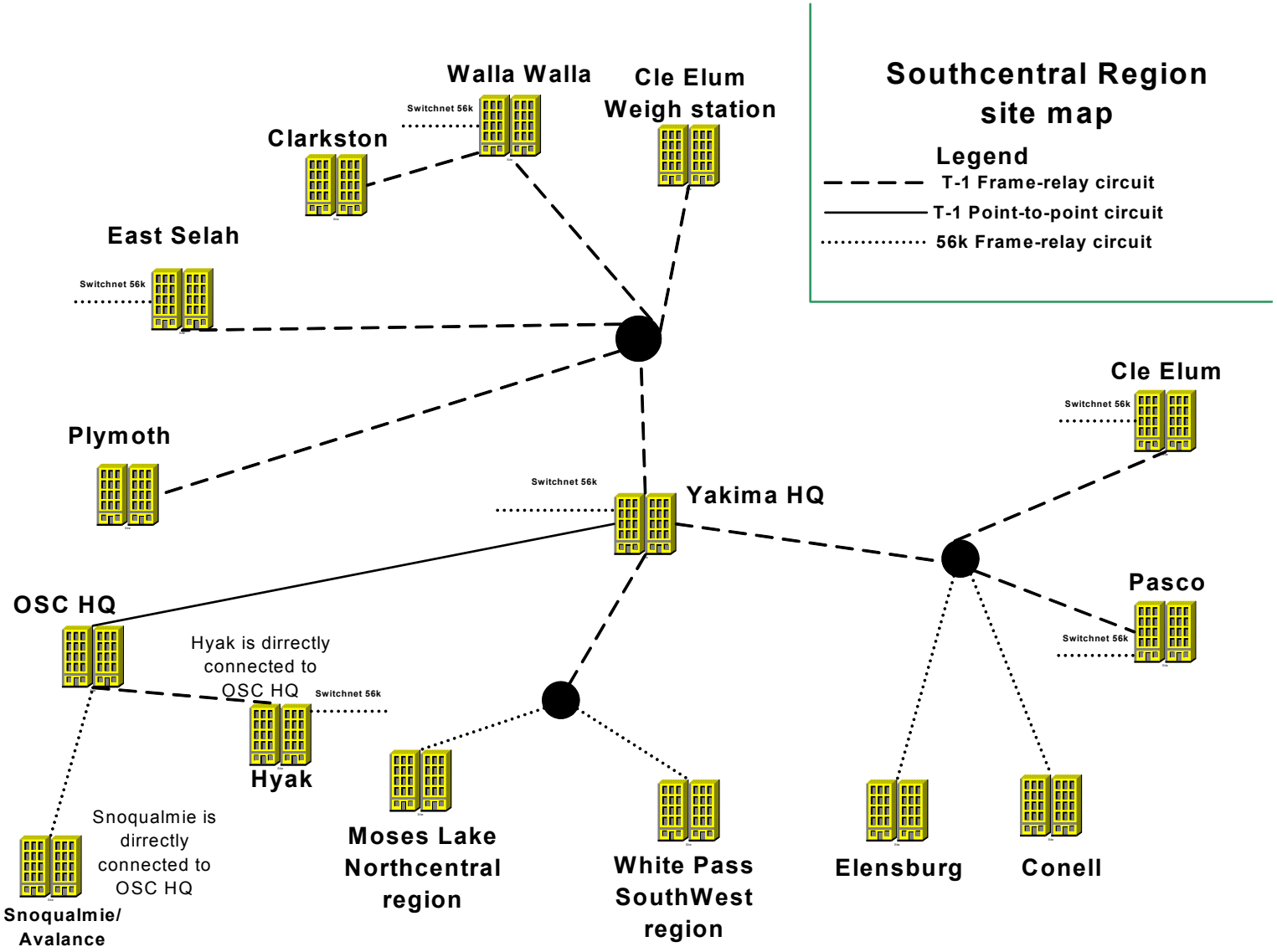


Figure 11: South Central Region Leased Line Network

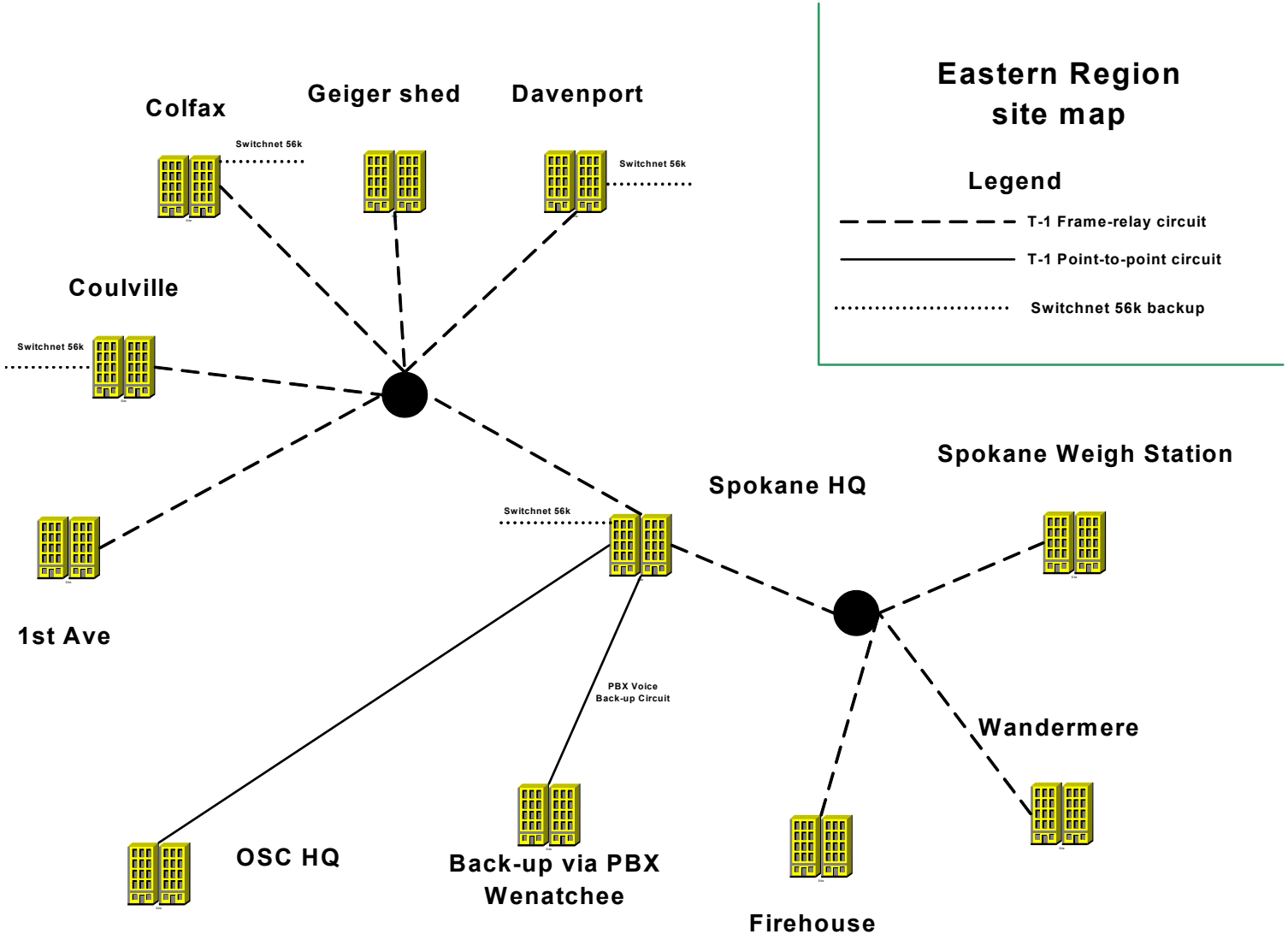


Figure 12: Eastern Region Leased Line Network

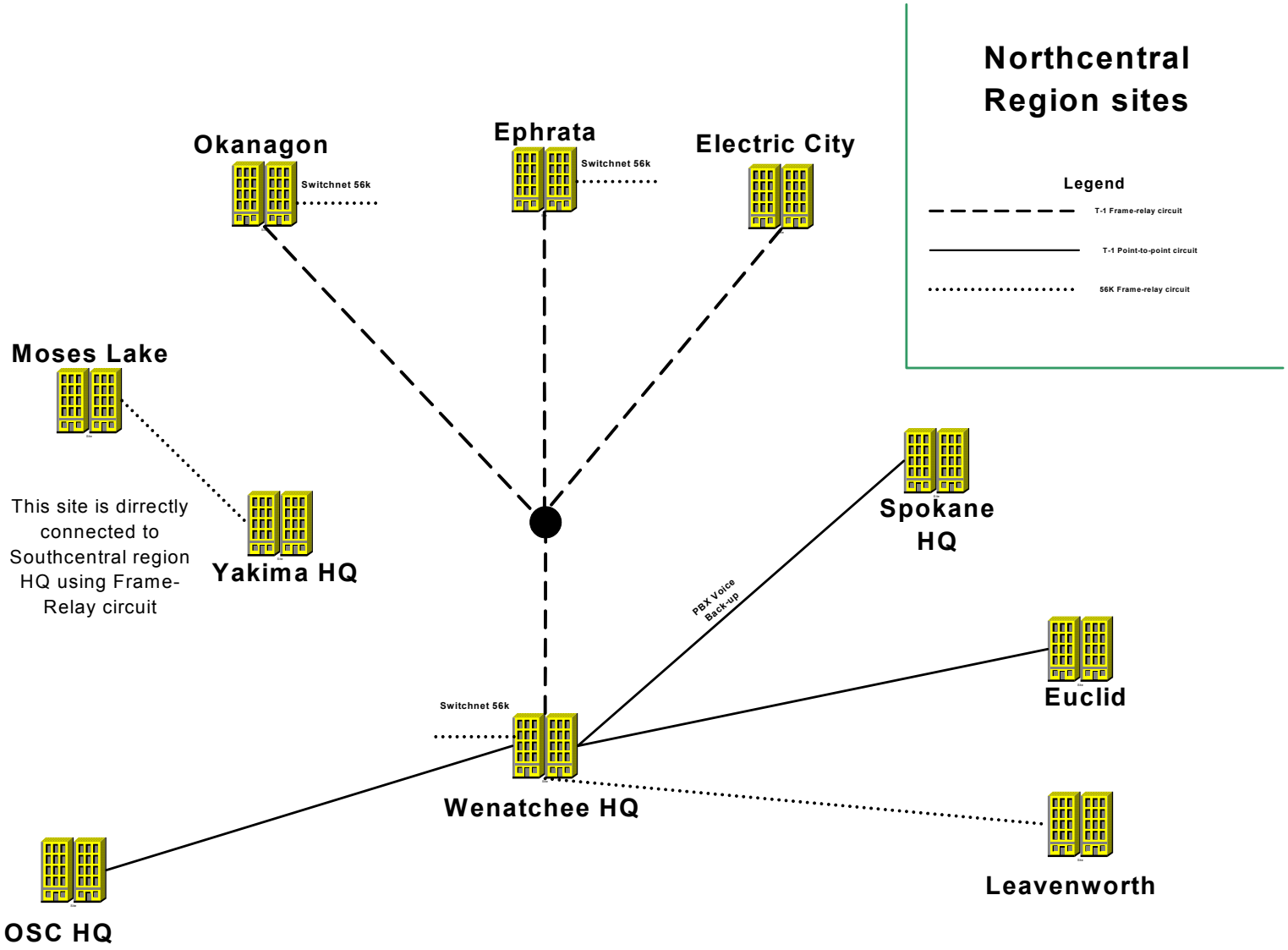


Figure 13: North Central Region Leased Line Network

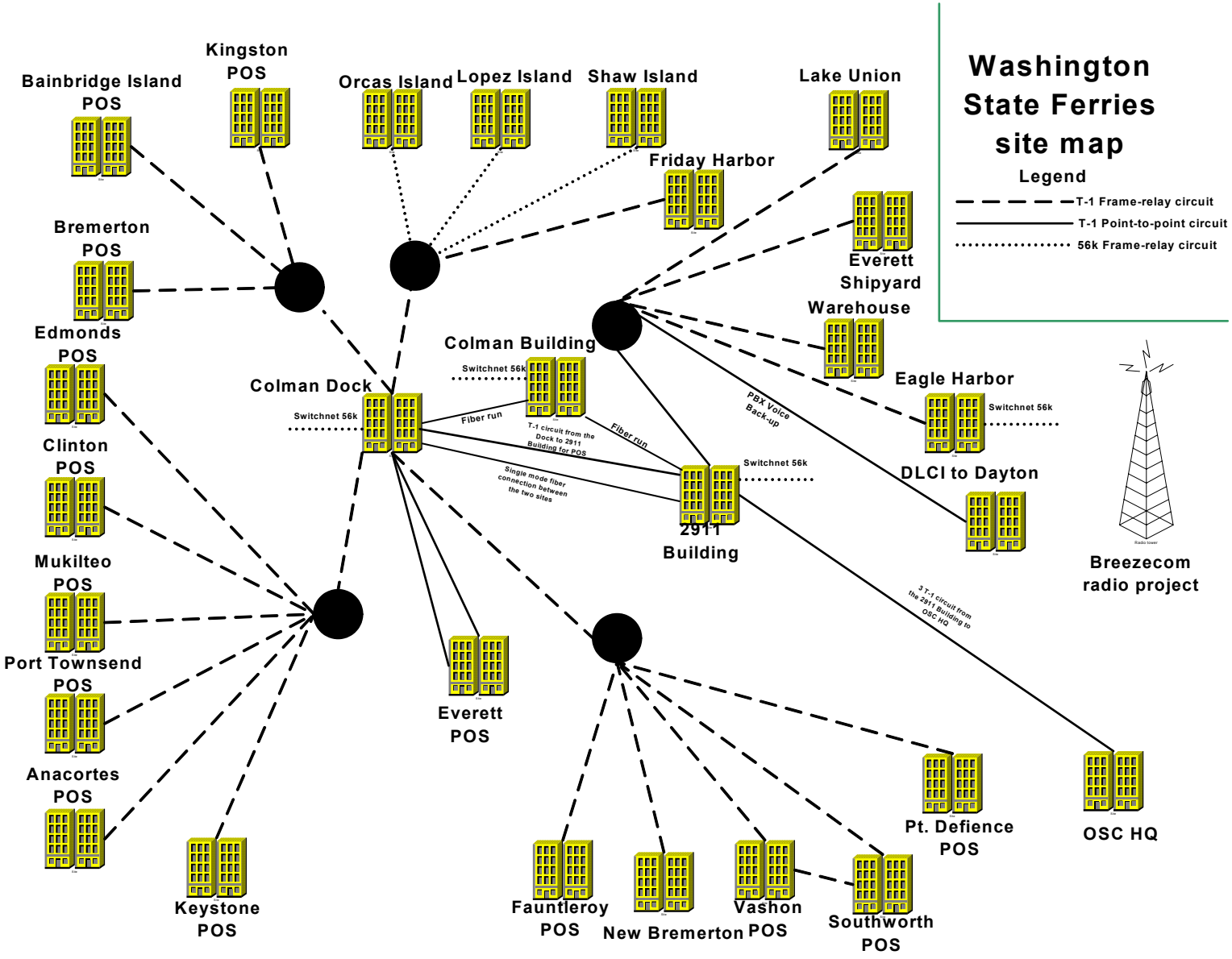


Figure 14: Washington State Ferries Leased Line Network

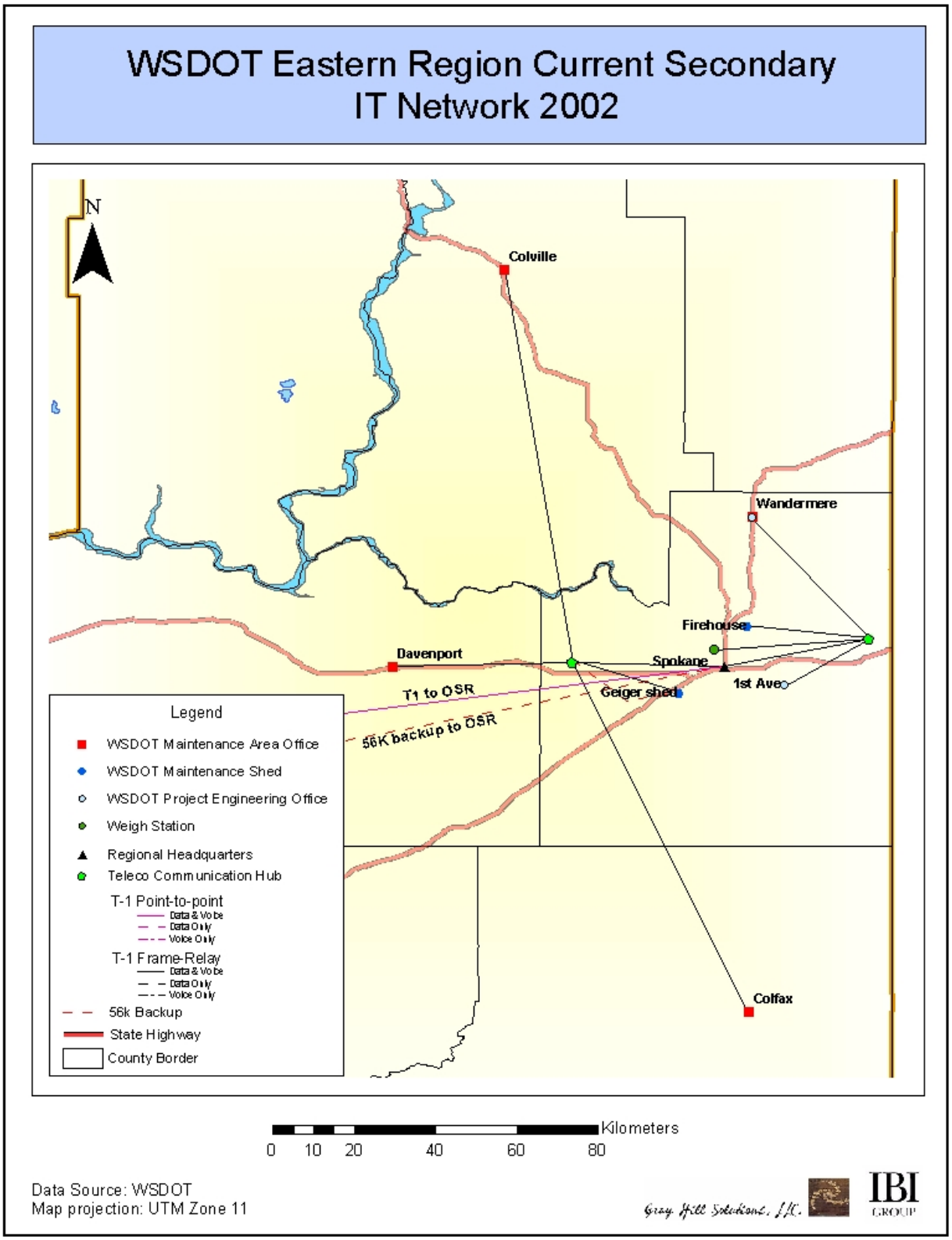


Figure 15: Example Regional Leased Line GIS Output

3.2.1.2 Fiber

In addition to the fiber shown in the above figures, some of the regions have built ITS fiber segments, or in the case of Northwest Region, an entire fiber ring. Currently, these fibers are generally used exclusively by the regional TMC to communicate with ITS field devices, including CCTV cameras, as well as low speed data devices such as VMS, traffic count stations, RWIS, etc. However, recent discussions have included analyzing the possibility of using this fiber (in special situations) for data connections between other WSDOT facilities.

Every region except for North Central includes some fiber optic cable (South Central's fiber network is limited to connecting two buildings across the street from one another.) This fiber is generally owned and maintained by WSDOT, with the exception being the Olympic Region, who built their fiber network around downtown Tacoma as a joint project with Tacoma City Fire Department. WSDOT owns half of that network's fiber.

3.2.1.3 WSF 802.11 Pilot Project

Washington State Ferries (WSF) has deployed 802.11 technology (commonly referred to as WiFi) on several of their vessels to track vessel location, real-time diagnostic/maintenance information and even voice communications with ferry operators. This implementation is still in pilot project mode while security issues are being worked out.

3.2.2 Communications Traffic

The types of video, voice and data traffic on the intra-regional communications network are identical to those described in Section 3.1.2 on the inter-regional network.

3.2.3 Utilization

As with the inter-regional links, WSDOT OIT tracks bandwidth utilization for all of the intra-regional links by remotely monitoring the routers and producing bandwidth utilization charts for each. For the purposes of this report, any segment that showed frequent occurrences of over 20% bandwidth utilization was considered a "high utilization segment."

Figure 16 indicates all of these intra-regional high utilization segments. As with the inter-regional connections, in developing this chart the high and low days of each month were discarded and the chart displays the range of usage for the remaining days.

The same general rules of thumb for bandwidth utilization apply, including:

- **Less than 20% Utilization**: Should not experience notable system slowdown
- **20-30% Utilization**: Will start noticing periodic system slowdown and may consider upgrading link bandwidth or other action to reduce utilization percentage
- **Greater than 30% Utilization**: Will likely notice regular system slowdown and occasional lost data; consider upgrading link bandwidth or other action to reduce utilization percentage

Almost all of these over-utilized segments are cases where multiple sites are sharing a frame relay T1 connection. What is important to note, is that in most of these cases, only one or two of the sites are "large" sites (i.e., heavy bandwidth users). However, when the network connection becomes slowed down, all of the sites on the shared T1 will experience network slowdown. The approach that has been used in dealing with these segments is to trim out the high bandwidth office from the frame relay cluster and provide a dedicated leased line for this office. This provides increased capacity for the office and to the other cluster members.

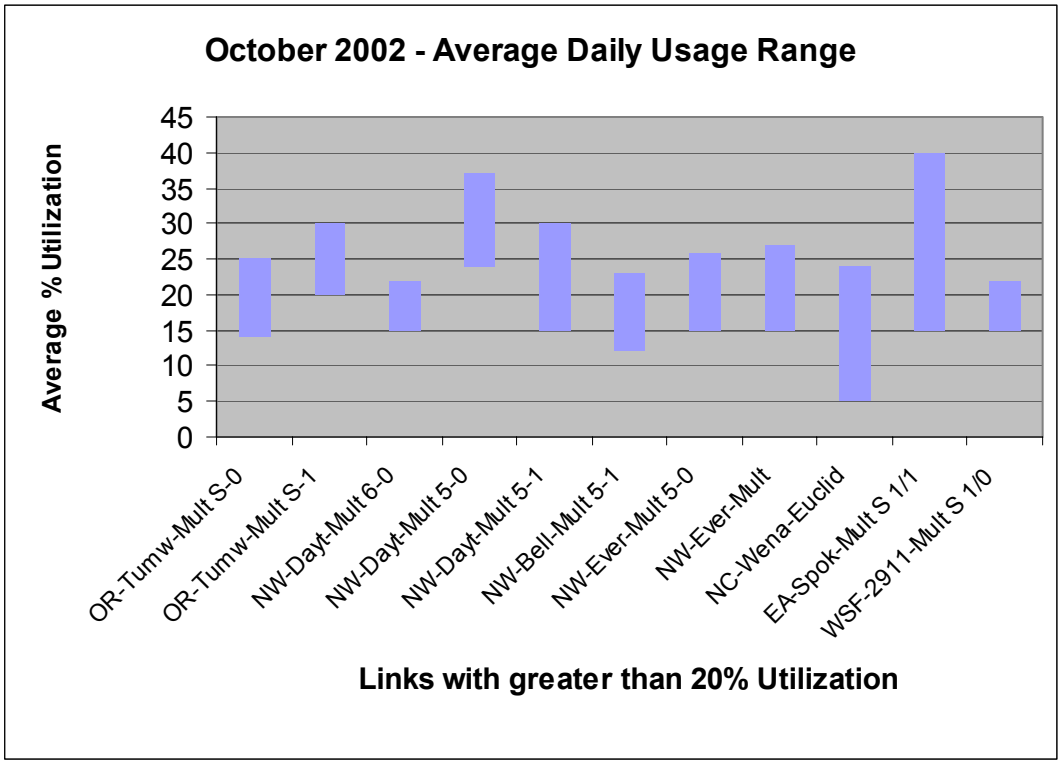


Figure 16: Intra-regional High Utilization Segments

3.2.4 Planned Upgrades

3.2.4.1 Enterprise/IT

As with the inter-regional communications links, there were several segments identified that may have different bandwidth links as compared to those illustrated in the network architecture schematics[5]. Therefore, many of these upgrades listed below may have already been implemented. These upgrades include (by region):

[5] Note: WSDOT OIT updates these Network Architecture schematics regularly. Some of these upgrades may have already been identified in recent updates.

Northwest Region

- **Dayton HQ to Corson**: Planned upgrade would include two T1s on this link.

- **Dayton HQ to Office of Urban Mobility**: Planned upgrade includes a direct T1 link between these two offices that is not indicated in Figure 8.

- **Dayton HQ to 'El Capitan' (shown on map as Everett Satellite)**: NW region IT is working together with the ITS group to investigate connecting these buildings using the ITS fiber ring, as opposed to (or in addition to) the leased line connection. The frame relay connection to Everett and other northern sites is one of the most heavily utilized connections in WSDOT's entire network. Figure 8 shows this as the connection between Dayton HQ and Everett North, which is shared with several additional sites. Migrating the connection to Everett Satellite to fiber, and then switching the leased lines up to Mt. Vernon (and other northern sites) would not only help network performance between Dayton HQ and Everett, but also to all of the sites sharing this connection.

Olympic Region

- **Tumwater HQ to Pt. Plaza**: Planned upgrade includes two T1s on this link, as opposed to the single T1 indicated in Figure 9.

- **Mildred Eng Office to Center Street Real Estate Office**: Planned upgrade includes one (or possibly two) T1(s) between these facilities. The Center Street Real Estate Office is not shown in Figure 9.

- **Mottman Bridge Preservation Office and Mottman Maintenance Shed**: Planned upgrade includes a T1 connection between the Olympia HQ and Mottman Bridge Preservation office (possibly illustrated in Figure 2) and both a fiber (for data) and a copper (for voice) connection between the Mottman Bridge Preservation Office and the Mottman Maintenance shed.

- **Future Gig Harbor Site**: A new site in Gig Harbor is planned to come on-line in early 2003 for the Tacoma Narrows Bridge. Bandwidth requirement has not been identified.

Southwest Region

- **Vancouver HQ to Kelso**: Planned upgrade includes two T1s on this link.

- **Vancouver HQ to Vancouver Office**: Planned upgrade includes two T1s on this link, as opposed to the single T1 indicated in Figure 10.

- **Hazel Dell Site**: Interview indicated that this site is no longer utilized by WSDOT, however, the Frame Relay T1s are still be used by remote CCTV cameras.

It was also noted in the Southwest Region interview that all of the T1s currently have a 56K back-up, which is being eliminated with no alternate back-up currently identified.

South Central Region

- **Yakima HQ to Ellensburg:** Interview indicated that the 56K frame relay connection illustrated in Figure 11 would likely be upgraded to a broadband connection in the near future. The upgrade could be a DSL or cable modem connection, depending on availability and pricing from local service providers.

Eastern Region

- **Remote Maintenance Sheds**: Planned upgrade includes up to 16 maintenance sheds (none of which are indicated in Figure 12) being added to the network in the near future and will utilize satellite broadband connections. At the time of the interview, WSDOT was testing these satellite broadband connections at several sites, but has since decided to proceed with full-scale deployment.

  Eastern Region had looked into other options for replacing the dial-up service to these maintenance sheds (many of which were at 24.4k speeds), but found that in most cases satellite broadband was the only option. Rather than split their network between some DSL, some cable broadband and some satellite, they decided to standardize as much as possible with one vendor and one solution.

North Central Region

- **Wenatchee HQ to Euclid**: Planned upgrade includes two T1s on this link, as opposed to the single T1 indicated in Figure 13.

- **Electric City to local ISP**: Interview indicated that the North Central IT staff is looking into connecting the Electric City facility to a local Internet Service Provider (ISP) using fiber being constructed by the Douglas and Grant County Public Utilities. This would improve the region's connections to the Internet and email, and would be the first leg of a future fiber network connecting the North Central and South Central Regions. The fiber networks being constructed by these counties as part of a larger scale effort (with NoaNet) are discussed in more detail in Section 3.7, Telecommunications Market Sector Review.

WSF

- **2911 Building to Olympia HQ**: Interview indicated a desire to upgrade from the existing 3 T1s to a DS3 connection, although no specific timeline for upgrade was identified.

3.2.4.2 Intelligent Transportation Systems (ITS)

Several segments of fiber were identified as probable upgrades in the immediate future. However, most of these were likely put on hold with the failure of Referendum 51. For the purposes of the Statewide Communications Plan, none of the potential upgrades was considered significant enough to warrant detailed discussion.

3.2.5 Growth

3.2.5.1 Enterprise/IT

The issues surrounding growth of Enterprise/IT network traffic are identical to those discussed under inter-regional Communications (Section 3.1.5.1). In summary, these issues include:

- General industry-wide trends toward increased bandwidth utilization;
- WSDOT's trend towards centralization of applications;
- WSDOT-specific "Big Bandwidth" applications and;
- Digitizing, storing and accessing construction drawings.

As discussed previously, it is anticipated that there will be a period of leveling off, or even a short-term decline in bandwidth utilization, due to the staff reductions triggered by the failure of Referendum 51. However, it is then anticipated that bandwidth requirements will eventually continue to grow due to the factors presented above.

3.2.5.2 ITS

The issues surrounding growth of the ITS network are similar to those discussed in the Inter-regional Communications (Section 3.1.5.2), most notably that bandwidth requirements and connectivity requirements will continue to grow as more devices are deployed in the field, and as devices are utilized differently and/or polled more frequently.

In addition to these issues, the intra-regional communications requirements include the ever-increasing desire for connection to and communications with more local municipalities, agencies, emergency service providers, etc.

The following series of tables identifies specific local municipalities and existing, planned and potential connection types by region.

WSDOT NORTHWEST REGION EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
Washington State Patrol, District 2 (Bellevue)	Video	Existing
City of Kirkland*	Data Video	Potential Potential
City of Redmond	Data Video	Planned Planned
City of Bellevue TMC*	Video Data	Existing Planned
City of Issaquah*	Video Data	Potential Planned

WSDOT NORTHWEST REGION EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
King County TMC	Video Data	Planned Planned
City of Renton TMC*	Video Data	Planned Planned
WSDOT Olympic Region TMC	Video Data	Existing Existing
City of Seattle TMC*	Video Data	Existing Planned
City of Tukwila*	Video Data	Potential Planned
SeaTac Airport*	Data	Planned
City of Kent*	Video Data	Potential Planned
City of Federal Way*	Data Video	Planned Potential
City of Auburn*	Data Video	Planned Potential
City of Maple Valley*	Data Video	Planned Potential
City of Woodinville*	Data Video	Planned Potential
City of Mercer Island*	Data Video	Planned Potential
City of SeaTac*	Data Video	Planned Potential
City of Des Moines*	Data Video	Planned Potential
Snohomish County	Data Video	Planned Planned
City of Everett*	Data Video	Planned Potential
City of Bothell*	Data Video	Planned Planned
City of Edmonds*	Data Video	Planned Planned
City of Mountlake Terrace*	Data Video	Planned Planned
City of Lynnwood*	Data Video	Planned Planned
Bellingham TMC	Data Video	Planned Planned
City of Bellingham	Data Video	Potential Potential
City of Mt. Vernon	Data Video	Potential Potential

* Source: Puget Sound Regional ITS Architecture; prepared for the Puget Sound Regional Council by IBI Group in association with PB Farradyne, Pacific Rim Resources, and the Battelle Memorial Institute; June 26, 2001.

WSDOT OLYMPIC REGION EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
WSDOT Northwest Region TMC	Data Video	Existing Existing
City of Tacoma	Data Video	Planned Planned
City of Bremerton	Data Video	Potential Potential
Tacoma Narrows Bridge	Data Video	Planned Planned
Pierce County	Data Video	Planned Planned
Camp Murray EOC	Data	Existing
Washington State Ferries	Data Video	Potential Potential
Washington State Patrol, District 1	Data Video	Existing Existing
WSDOT Southwest Region	Data Video	Potential Potential
Tacoma Fire Department	Video	Existing

WSDOT EASTERN REGION EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
WSDOT Central Washington TOC	Video Data	Potential Potential
WSDOT Olympic Region TMC	Video Data	Potential Potential
Washington State Patrol, District 4 (Spokane)	Video Data	Planned Planned
City of Spokane	Video Data	Existing Existing
Spokane County	Video Data	Existing Existing
Spokane Transit Authority	Video Data	Existing Existing
Spokane Regional Transportation Council	Video Data	Existing Existing

WSDOT CENTRAL WASHINGTON TMC EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
WSDOT North Central Region	Data Video	Existing Existing
Washington State Patrol, District 2 (Bellevue)	Data	Potential
Washington State Patrol, District 3 (Union Gap)	Data Video	Existing Existing
Washington State Patrol, District 6 (Wenatchee)	Data	Potential
City of Richland	Data	Potential
City of Kennewick	Data	Potential
City of Pasco	Data	Potential
City of Wenatchee	Data	Potential

WSDOT SOUTHWEST REGION EXISTING AND DESIRED COMMUNICATIONS LINKS		
Agency	**Communications Needs**	**Status**
ODOT Traffic Operations Management Center	Data Video	Planned Planned
Clark County TMC**	Data Video	Planned Planned
City of Vancouver TMC*	Data Video	Planned Planned
City of Camas TMC**	Data Video	Planned Planned
RTC VAST Data Warehouse**	Data	Planned
WSDOT Olympic Region TMC	Data Video	Potential Potential
WSDOT Central Washington TMC	Data Video	Potential Potential

3.3 PHONE/PBX NETWORK

WSDOT has configured and maintained a Private Branch Exchange (PBX) telephone network that allows inter-office dialing between WSDOT offices, without the use of the public switched telephone network. The primary feature of this network is the ability to use 4-digit dialing between any connected WSDOT offices in the state, eliminating any long distance charges on

** Source: Vancouver Area Smart Trek (VAST) Operational Concept, prepared by IBI Group for VAST; June 2002.

such telephone calls. Figure 17 illustrates the Network Architecture of the WSDOT PBX network.

The size and complexity of the WSDOT telephone network is comparable to that of a small telephone company. The reliability of the network is very important to the daily operation of WSDOT, and a key requirement of any contemplated enhancements or expansions is that the network remains reliable in the event of any major or minor emergencies that require attention by WSDOT staff.

3.3.1 Existing Infrastructure and Architecture

Telephone service in every WSDOT office is provided using a PBX. A PBX provides the ability to do three or four digit dialing to other phones to which it is connected. To provide access to locations outside the office, the PBX has trunk lines that can be connected to the Public Switched Telephone Network (PSTN) and to other PBXs in other offices.

The WSDOT network has been configured to interconnect a large group of PBXs as shown in Figure 14, allowing voice communication between WSDOT offices using the WSDOT network. In general, smaller PBXs are connected to main hubs at Olympia, Dayton, Yakima and Spokane. These main hubs are in turn interconnected, with Olympia being the central switch location.

The interconnection between PBXs can be carried on leased lines or over channels on a microwave system. Many of the PBXs are capable of Voice over IP (VoIP) communication, which would allow the interconnection between PBXs to occur over an Ethernet link. To date this feature has not been implemented.

The PBXs have been procured from a number of different manufacturers, and have differing capabilities, but they use standard interfaces that allow interconnection and statewide 4-digit dialing.

3.3.2 Planned Upgrades

As the number of telephone extensions in use increases over time, there comes a point (at 9999 extensions) that 4-digit dialing cannot be provided to all users. The WSDOT Network has reached this point. WSDOT has the option of introducing special dialing codes to reach each particular PBX, from where the user could dial a 4-digit extension to reach another user through that PBX, but a cleaner and more universal approach is to switch to 5-digit dialing.

This upgrade will not impact the PBX communication requirements, but it does require software upgrades to the PBXs. At this time, due to the results of Referendum 51, the previously anticipated staffing increases will likely not be experienced, and this upgrade can most likely be postponed.

3.3.3 Communications Traffic and Utilization

For voice networks running on traditional channels, the traffic analysis is based on the call volume, which is a function of the number of calls and their duration. This information can be

extracted from each PBX using the CDR (Call Detail Record), which records the origination and destination number for each call, and its duration.

The sizing of the trunks on a PBX is based on established statistical models ("Erlang Tables") that are driven by the call volume and desired level of blocking. Many PBXs will provide reporting on the call volume on the trunks. These reports can be used directly with the Erlang Tables to provide an estimate percentage of calls that were blocked due to lack of trunks. Telephone companies strive for less than 1% blocking, which means that no more than 1% of long distance calls would get a "fast busy" indication that all trunks are in use. On cellular telephone networks, blocking can be as high as 5%.

Alternately, it is possible that a review of the call volumes and CDR data could suggest that the number of trunks is greater than what is required.

3.3.4 Growth

Unlike data traffic, voice traffic on a phone network is more directly related to staffing levels and the number of connected telephones. The change in utilization is often a more steady and predictable parameter than data traffic, which can change significantly as applications and user profiles change.

One circumstance that can impact voice traffic patterns is office reorganizations, where groups that frequently communicate via telephone are moved to different offices.

In general, the increase (or decrease) in the voice communication links will be proportional to the staffing levels. It is possible that Referendum 51 will have a negative impact on the growth of voice traffic, until staffing levels eventually increase again in the future.

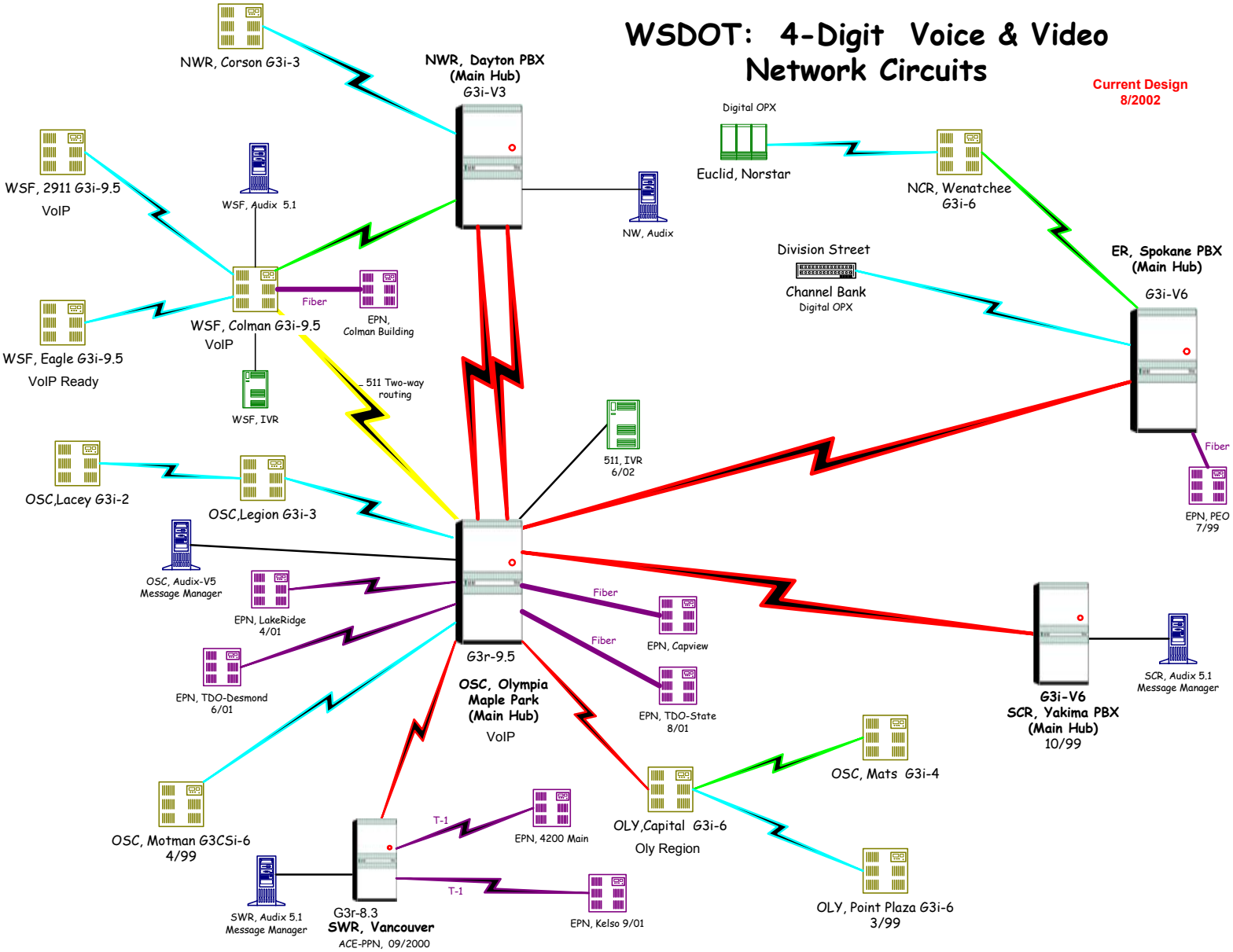


Figure 17: WSDOT PBX Network Diagram

3.4 CENTER-TO-FIELD VOICE

WSDOT's operations rely heavily on the ability to communicate with staff in the field, whether they are maintenance personnel, construction administration, Incident Response or engineers working on field design. It is also extremely important for field personnel to be able communicate with one another. To support these center-to-field and field-to-field voice communications, WSDOT employs two different technologies: cellular phones and radios. Various private communications service providers own the cellular phone networks. WSDOT employees use different providers based on the services available within the region. For the purposes of the Statewide Communications Plan, little further discussion is warranted on the usage of cellular service.

Thus, the remainder of this discussion will focus on the WSDOT voice radio network.

3.4.1 Existing Infrastructure and Architecture

The WSDOT radio network encompasses three primary components:

- **Microwave Backbone Network**: Point to point, long distance, high bandwidth (generally analog or digital DS3) connections; primarily in the 6Ghz microwave range, shared with WSP.
- **Radio Distribution Network**: Point to multipoint, medium distance, 800MHz trunked[6], networked[7], radio system for office-to-office, office-to-field and field-to-field voice communications.
- **Back-Office Connections**: Equipment and electronics that integrate the microwave and radio systems, connect to computer aided dispatch (CAD) systems, and connect to agency networks (LAN/WAN) for data communications (as applicable).

Figure 18[8] is a schematic illustrating these wireless network components. Two different facility scenarios are displayed in Figure 18:

- **Co-located Facilities**: Buildings where WSP and WSDOT are collocated. This allows for easy interconnection between the two different radio networks and the microwave network, as well as between the LAN/WAN networks of both agencies and the microwave network.
- **"Nearby Facilities"**: Buildings where the WSDOT facility is close to the site that holds the microwave and radio equipment (usually a WSP facility.) In this case, any connection

[6] Trunked: Mobiles and repeaters automatically select the best frequencies (channels) to use based on network utilization, availability and required circuit.
[7] Networked: System automatically connects with appropriate mobiles and repeaters throughout the network to facilitate communications with the intended mobile.
[8] WSP has a different radio communications network in the VHF range that is also included on this schematic and is discussed below.

between the WSDOT LAN/WAN and the microwave equipment would have to include an outside plant connection, either fiber or copper, owned or leased.

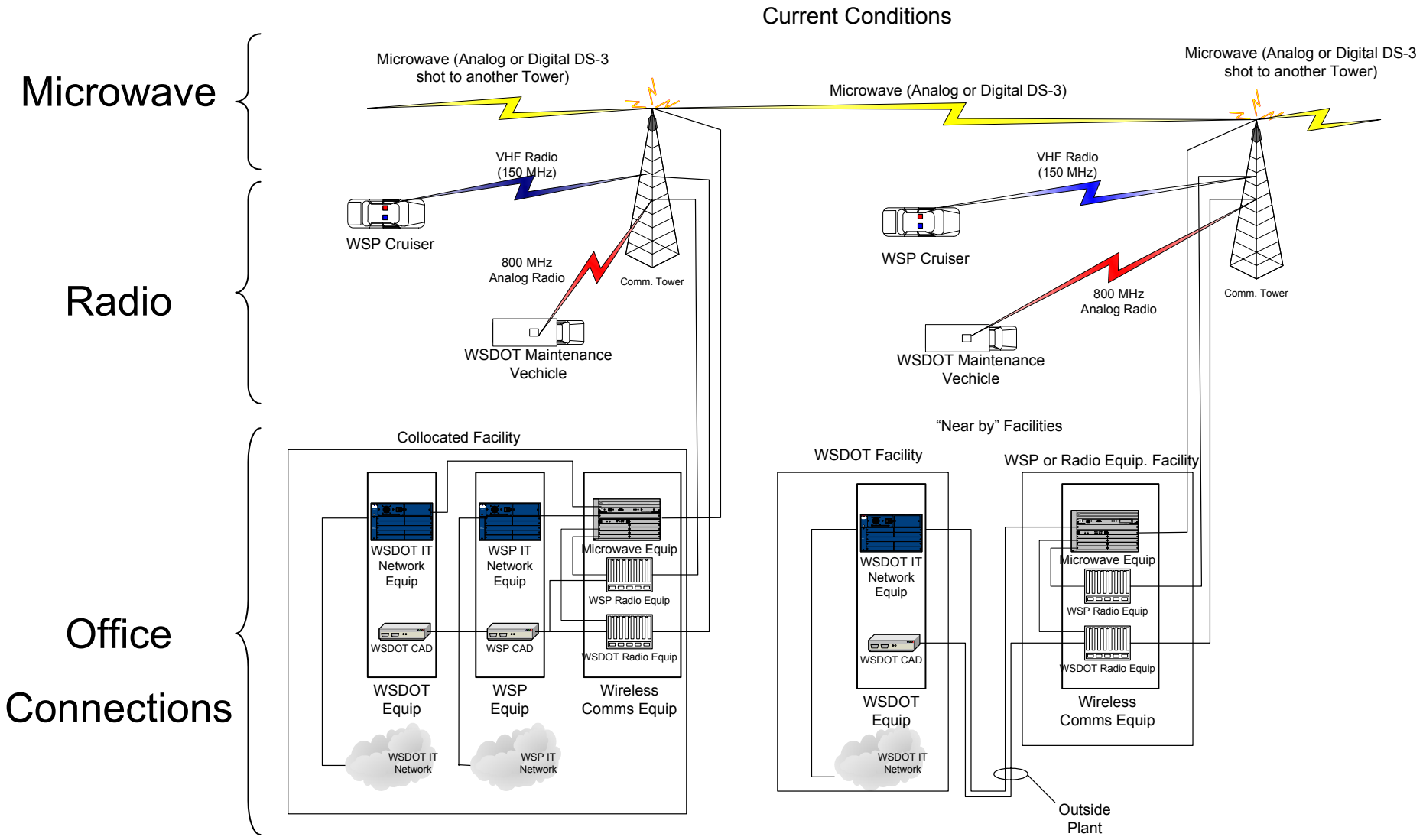


Figure 18: Components of WSDOT Wireless Network

3.4.1.1 Microwave Network

The majority of the backbone microwave network that WSDOT utilizes for radio communications was originally built—and is currently maintained —by the WSP. WSDOT has added lower bandwidth extensions to this network in order to reach sites that were not originally on the WSP network, and over time, the microwave network has increasingly been considered a key piece of "joint owned" infrastructure[9]. Figure 19 illustrates the WSP/WSDOT microwave backbone network. This map includes the following elements:

- **Facilities and Sites**: including both WSP and WSDOT microwave sites and key WSP facilities;
- **Microwave Paths**: including both WSP and WSDOT paths. As indicated on the map, some of the WSP paths are analog only, some are digital only, and some include parallel analog and digital paths. The WSDOT paths are primarily lower bandwidth, analog paths.
- **WSP Districts**: The district boundaries indicated are WSP districts (not WSDOT regions), as this map was developed by WSP.
- **Sites and paths owned by others**: There are a small handful of sites and microwave paths indicated as "owned by others", most likely the Department of Natural Resources (DNR), who also shares bandwidth on the microwave network with WSP and WSDOT.

With the signing of the Joint Operations Policy Statement (JOPS) in February of 2002 (developed and accepted by both WSDOT and WSP), the joint ownership relationship has been further formalized. A section of the JOPS document specifically addresses the wireless network. This section includes the following statement:

*"**Policy:** The WSP and the WSDOT agree to support a shared vision to create a coordinated and integrated wireless transportation communications for the safe, effective, and efficient protection of the traveling public. The agencies mutually agree it is their joint goal to implement a statewide wireless mobile communications network that is fully interoperable between agencies and workgroups to provide needed services to our field forces and support groups to benefit the citizens of this State…*

The WSP and the WSDOT agree to view their respective wireless communication systems as a single wireless system to plan for and foster interoperability among existing wireless networks and future wireless development that meets the requirements of local, state, and federal public safety."

With these goals in mind however, there are some significant challenges before the agencies to reach true interoperability. These challenges will be discussed in more detail below in Section 3.4.1.2, 800 MHz Radio Distribution.

Currently, the microwave backbone network is generally operating near capacity due to a number of reasons, including:

[9] There are actually a number of state and federal agencies that use some channels on the microwave network; however, WSP and WSDOT are the primary users.

- **Number of Users**: WSDOT and WSP each utilize approximately 1/3 of the available channels on the microwave network, both with more individual users than was originally intended. The other 1/3 of the channels are used by other state and federal agencies, including the FBI, DNR, Department of Fish and Wildlife, Parks Department, and Liquor Control Board, to name a few.

- **WSP Data**: While the network was originally built for voice radio communications, WSP does use it for data communications, primarily between Tumwater and the District offices. The data traffic between districts is generally fairly low, although it may increase when WSP completes the upgrade of its Computer Aided Dispatch system.

- **WSP Phone Network**: In addition to data communications, WSP utilizes the microwave network for their inter-office 5-digit dialing phone network.

- **Interoperability with Local Emergency Service Providers**: WSP would like to keep some channels available on the microwave network to be used for interoperability with other local agencies and emergency service providers.

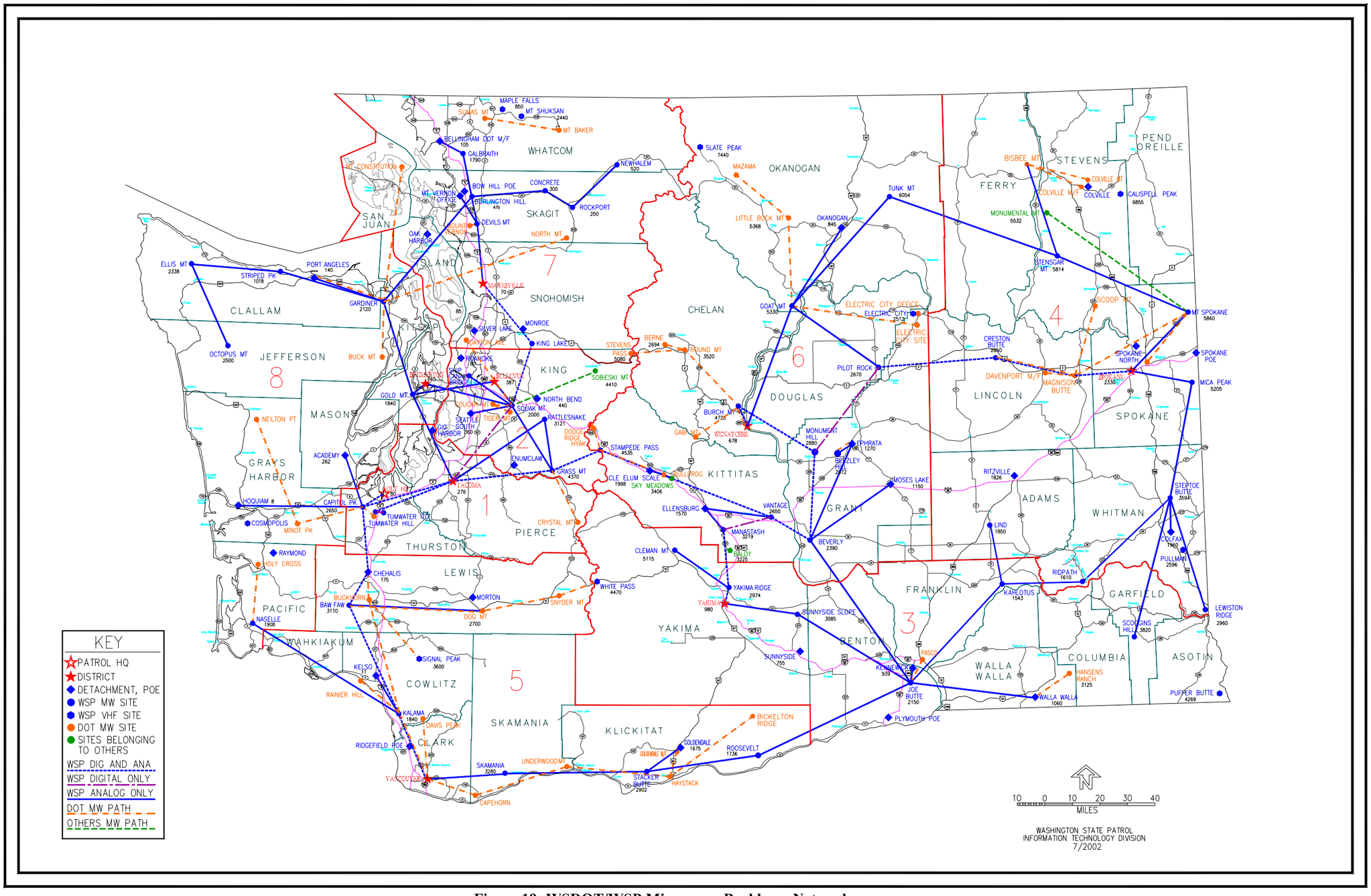


Figure 19: WSDOT/WSP Microwave Backbone Network

3.4.1.2 800 MHz Radio Distribution

WSDOT owns an extensive, statewide, 800MHz radio network. As discussed above, this is a trunked and networked analog radio system and includes repeater stations, mobile radios (installed in the WSDOT vehicles) and portables (hand held units) with over 4000 subscriber units. Because it is a networked system, mobiles, portables and dispatch stations can all communicate with one another over very large distances without the required intervention of a third party (or dispatcher). As discussed previously, the radio network uses the microwave backbone for longer distance communications.

displays the WSDOT 800MHz Radio network. This map includes four elements:

- **Existing Sites**: An existing site (usually either a facility or mountaintop tower location).
- **Proposed Sites**: There are a small handful of proposed new sites, primarily to mitigate coverage problems.
- **Poor Coverage Area**: There are a number of poor coverage pockets, primarily in rural areas and caused by geological barriers such as mountains, valleys, etc.
- **Interference**: There are a number of places with high interference, generally in urban areas along I-5 and I-90. This interference is primarily caused by NexTel; a private wireless communications provider of both cellular and radio services. NexTel's radio service operates at frequencies in close proximity to the WSDOT radio system.

There are a number of issues regarding the WSDOT 800MHz radio network that warrant further discussion, including their desire to migrate from the 800MHz band into the 700MHz band. Some of these issues are detailed below.

3.4.1.2.1 Interference

The primary factor driving WSDOT's plan to migrate from the 800MHz range to the 700MHz range is the interference problems discussed above. Interference is caused by harmful same-band digital systems, most notably NexTel. A short term, "band-aid" fix is discussed in Section 3.4.2, but only migration into the 700MHz band is considered a long-term solution.

3.4.1.2.2 Bandwidth

The 800MHz system is operating near capacity with voice traffic only. WSDOT has indicated a strong desire to investigate center-to-vehicle data communications (discussed in more detail in Section 3.5). One of the factors initiating WSDOT's desire to migrate to the 700MHz band is the additional bandwidth that would be available. This additional bandwidth is anticipated to adequately address WSDOT's center-to-field voice and data communications needs.

3.4.1.2.3 Interoperability and Project 25

Occasionally in cases of very large accidents, emergencies (fire, flood, earthquake, etc) and regional events, multiple agencies are called upon to respond and work together. Recently, there have been a number of instances across the country where responding rescue personnel from

federal, state, and local public safety agencies discovered that coordinating their efforts was extremely difficult because radios from each agency used different frequencies and signaling techniques. In many cases, on-scene commanders were forced to borrow radios from one another to coordinate their crew activities. The following excerpt[10] describes efforts that have been underway for a number of years to mitigate this problem:

"*To address the problem of interoperability as well as make better use of scarce radio frequencies, in 1989 the Association of Public Safety Communications Officials International (APCO) established Project 25 (P25). Representatives from Federal, state, and local governments began an effort to develop a set of common technical standards for land mobile radio systems…*

P25 is not a single standard but really a number of individual protocols that can be mixed and matched. A "Project 25 compliant" system may really use only a few of the many standards. For instance, a P25 system may be conventional or trunked, use encryption or transmit in the clear, and carry voice, data, or both.

P25 systems use what is called the Common Air Interface (CAI). This standard specifies the type and content of signals transmitted by compliant radios. One radio using CAI should be able to communicate with any other CAI radio, regardless of manufacturer.

At present, most public safety channels are 25 kHz wide. Current P25 radios are designed to use 12.5 kHz wide channels, allowing two conversations to take place where only one used to fit. Eventually, P25 radios will use 6.25 kHz channels, allowing four times as many conversations compared to analog.

P25 radios must also be able to operate the old way, in analog mode on 25 kHz channels. This is called backward compatibility, and allows agencies to gradually transition to digital while continuing to use older equipment."

As discussed previously, there is strong desire between WSDOT and WSP to achieve interoperable radio communications. However, there is no easy solution regarding how this interoperability should be achieved. While both agencies plan on migrating to P25 compliant systems, WSDOT intends to migrate their voice and data traffic into the 700MHz range (for reasons detailed above), while WSP plans on staying in the VHF range, to achieve interoperability with other local and federal public safety and emergency response personnel. Most likely, the WSDOT-WSP interoperability solution will eventually involve some sort of cross-band solution at either the mobile unit level or, preferably, at the repeater/base station level.

[10] Excerpt taken from "**THE CASE FOR APCO PROJECT 25 ",** by Dan Veeneman which first appeared in the June 2000 issue of Monitoring Times

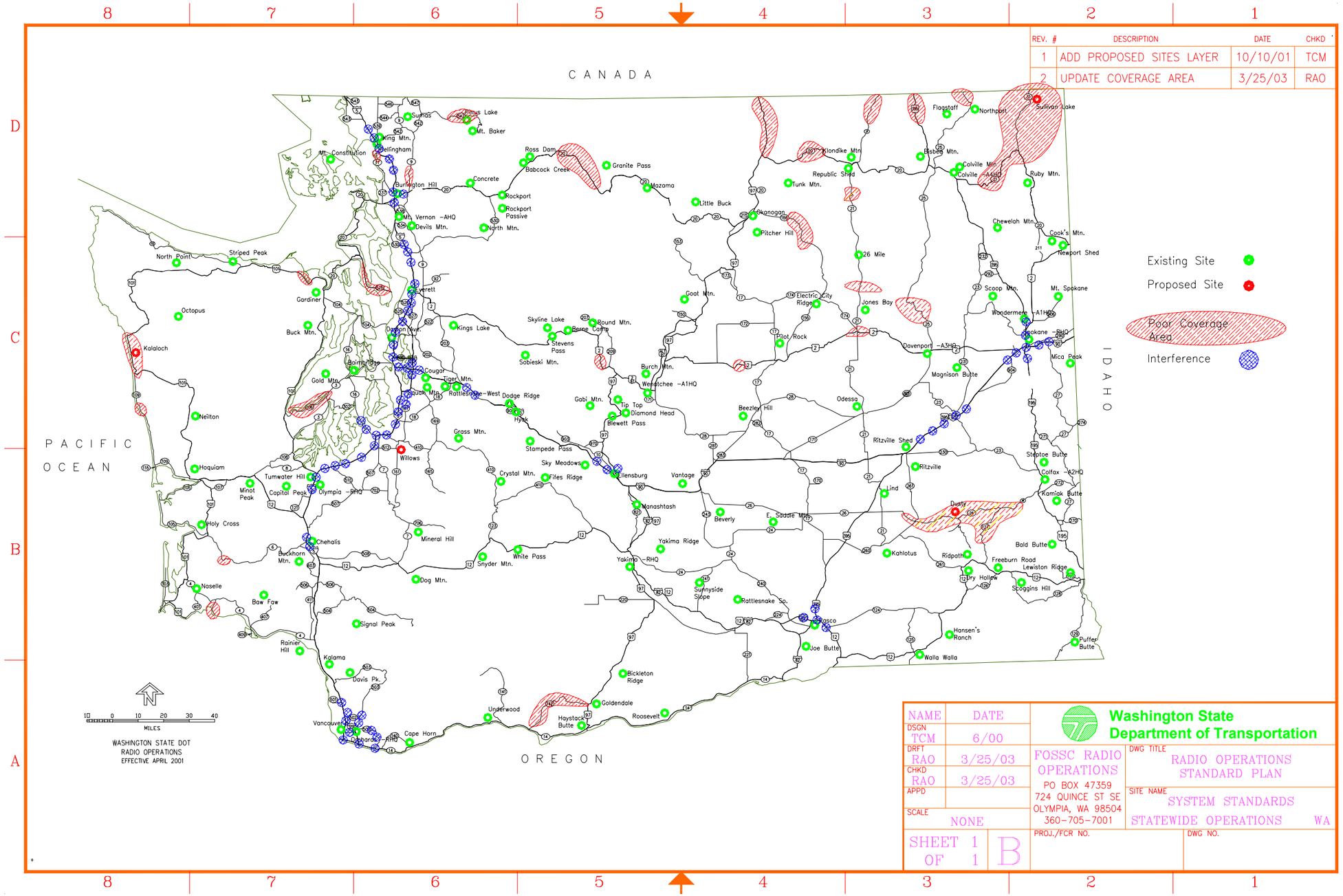


Figure 20: WSDOT Radio Network Map

3.4.2 Planned Upgrades

Figure 21 displays some of the proposed upgrades to the different elements of the WSDOT/WSP wireless network. These will be discussed in more detail in the subsequent sections on microwave and radio networks, but can be summarized as follows:

- **Microwave**: Plans are in place for certain segments of the microwave network to be upgraded to OC-3 capacity. Eventually these segments will complete three different OC-3 rings, bringing both added capacity (bandwidth) as well as increased reliability (redundancy) to the network.

- **Radio**: Both WSDOT and WSP have planned upgrades to their respective radio systems. For WSDOT, the intention is to migrate to the 700MHz band for reasons discussed above. This upgrade will also involve switching to P25 compliant digital equipment. WSP intends on staying in the VHF band, but upgrading to P25 compliant digital equipment.

- **Office Connections**: Although not specifically illustrated in Figure 21, both the radio and microwave upgrades will require upgrading the communications equipment labeled as "Office Connections" in the diagram. This is also where the "cross band" integration between WSP and WSDOT radio systems would likely occur. Finally, this is where the connection between the WSDOT WAN and the microwave network would occur, to put data on the microwave network. This will be discussed in more detail in Section 3.4.3, on Communications Traffic.

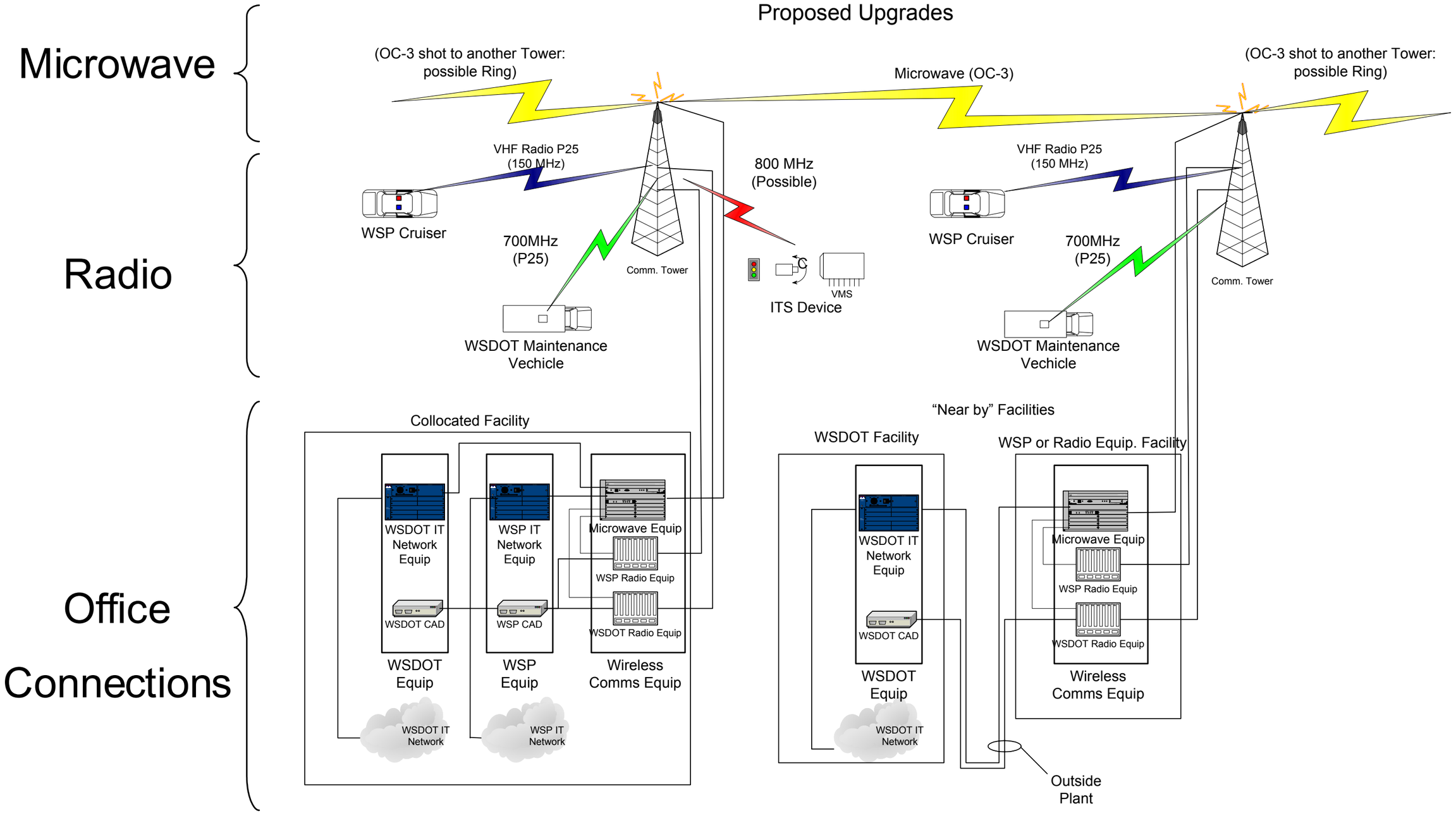


Figure 21: Proposed Upgrades to WSDOT/WSP Wireless Network

3.4.2.1 Microwave Backbone

WSDOT and WSP are currently working together to develop plans, identify funding and determine roles and responsibilities for upgrading the backbone microwave network. As discussed above, the intention is to upgrade the various DS-3 links illustrated in Figure 19 to become OC-3 links and eventually OC-3 rings. The agencies ultimately plan for three different OC-3 rings as illustrated in Figure 22. They refer to these future rings as the South Loop, North Loop and East Loop.

The purpose for the upgrade is to increase both backbone capacity (bandwidth) and reliability (redundancy.) The jump from DS-3 to OC-3 would triple the backbone bandwidth (as discussed in Section 2.4), opening up opportunities for WSDOT to utilize the backbone for uses other than voice radio communications, including data and the PBX network. Additionally, OC-3 rings are extremely reliable by nature. If a path is somehow cut or blocked, the communications traffic is automatically rerouted using the opposite side of the ring.

A decision package has already been submitted for the upgrade of the South Loop. The other two loops are slated for upgrade over the next couple of years, as funding becomes available.

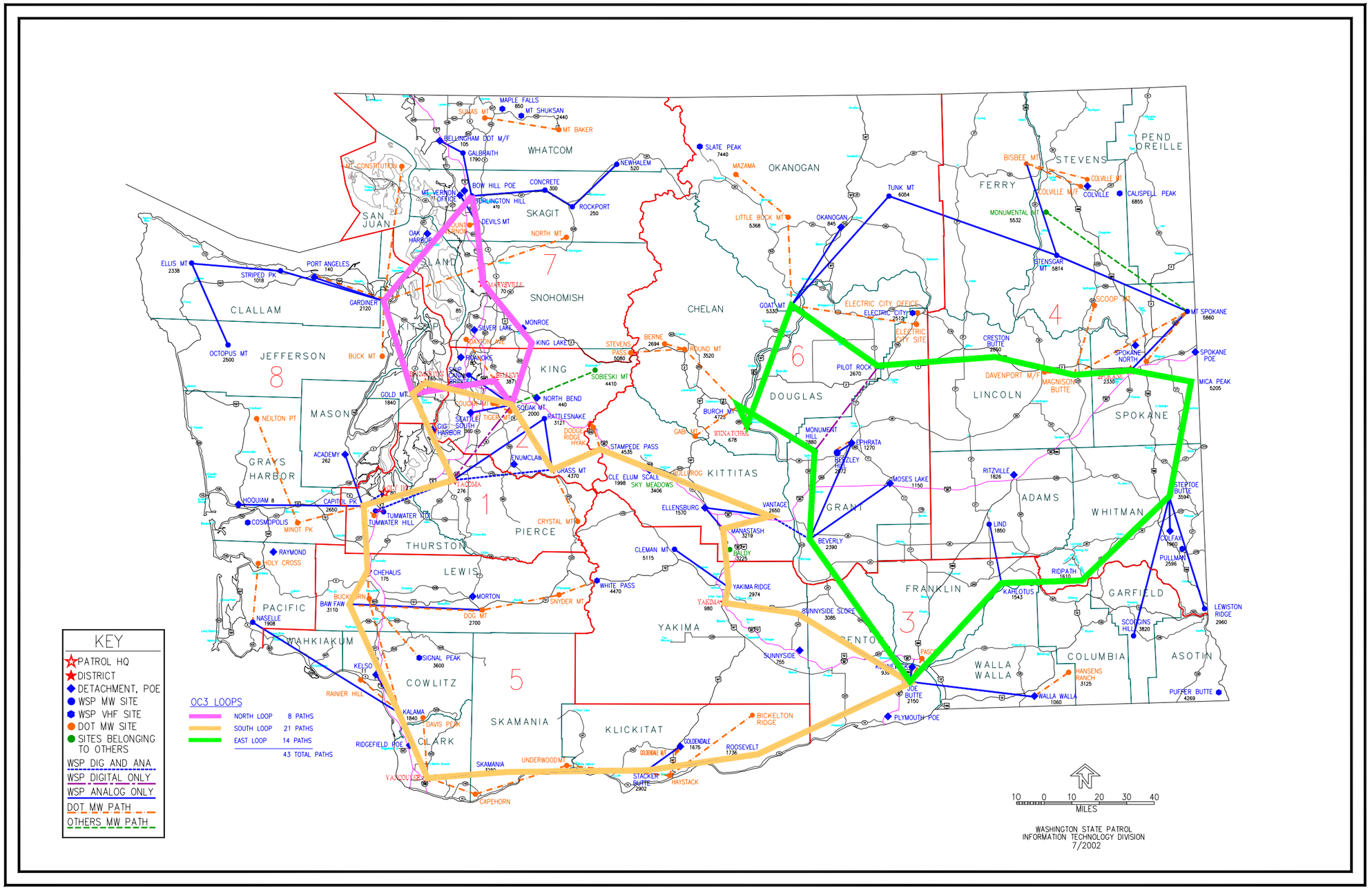


Figure 22: Proposed Upgrades to Microwave Network

3.4.2.2 Radio Network

The upgrade path for the radio network is a little less straightforward. WSP has already begun the process of their upgrade, by ordering some P25 equipment. A decision package has been submitted to upgrade to all new P25-compliant mobile units (over 900 units). WSP does not currently plan on upgrading their voice radio system to 700Mhz.

WSDOT's radio migration path is even more complex. First of all, there are a number of issues in regards to the 700MHz band, primarily its availability. While the FCC has allocated 24MHz of spectrum for public safety use in what is commonly known as the 700MHz band (actually 764-776 and 794-806 MHz), this band is, in some cases, still currently in use by UHF TV stations[11]. In addition to availability concerns with the bandwidth, the upgrade itself will be very disruptive to WSDOT operations. Equipment "change outs", both at the repeater level and at the mobile/portable level, do not happen overnight and will need to be deployed in a strategic, phased approach to ensure that WSDOT operations experience minimal interruption.

However, with those concerns in mind, WSDOT is proceeding with developing migration plans, due primarily to the interference problems discussed previously.

WSP has show interest in migrating their data communications to 700Mhz due to the bandwidth available, to support applications such as in-vehicle Internet access, email and records (including mug shots) to the vehicle.

3.4.3 Communications Traffic

Except for a handful of exceptions, WSDOT uses the wireless network primarily for voice communications to field personnel. Some of these exceptions are discussed in Section 3.5,Center-to-Field Data and Video. As far as the microwave backbone network is concerned, WSDOT is using this network exclusively for voice communications, with a sole exception: WSDOT and WSP have worked together to test a T1 data connection between Olympia and Vancouver on the microwave network. This connection has since been put into full operation and will continue to be utilized by WSDOT for data traffic.

WSP uses the microwave network for their voice, data and PBX needs.

3.4.4 Utilization

The microwave network is operating at near capacity, particularly along the I-5 and I-90 corridors. Both WSDOT and WSP indicated that the number of users on the network is much higher than was originally planned for. Additionally, WSP originally built the network to support voice communications to field personnel, and has since added both data and the PBX network to the microwave backbone.

[11] The FCC has set a date of 2006 to convert those frequencies from commercial broadcasting to public safety communications.

3.4.5 Growth

The number of voice users of the network is not anticipated to grow very much in the near future, however, the use of the network for data is expected to continue to expand.

3.5 CENTER-TO-FIELD DATA AND VIDEO

There are two main groups of communications needs under the heading of center-to-field data and video communications:

- Center-to-Vehicle
- Center-to-Field Device

These are discussed in more detail below.

3.5.1 Center-to-Vehicle

There are two programs in place currently that have center-to-vehicle data requirements: the Incident Response Team (IRT) Program and the "Snow Management" Pilot Project.

3.5.1.1 Incident Response Team

The IRT Program is viewed as a success by both WSDOT management and the general public. As described on the WSDOT website:

"*IRT staff are a specially trained group of WSDOT maintenance employees who respond to blocking incidents on our state's freeways and highways. Their main function is to clear roads and help drivers and restore the normal flow of traffic as safely and quickly as possible…*

Incident Response personnel are available 24-hours a day, seven days a week to provide traffic control, traffic rerouting, mobile communications, and assistance in incident clearance and clean up. This also includes helping motorists with a flat tire, jump starts, a gallon of gas, and many other types of motorist assistance."

Figure 23: Example WSDOT IRT Truck Exterior and Interior

The IRT project began as a pilot project covering the floating bridges during the Goodwill games in 1989, and has since grown to over 35 segments of roadway and 44 vehicles in all WSDOT regions. IRTs have a 90-minute clearance goal for all incidents.

In order to facilitate both IRT reporting and incident response, operators in most regions use laptop computers with wireless connections. There is some desire for the ability to send digital images of current conditions from the scene back to the TMC or regional HQ, particularly in the case of major incidents and emergencies. While this capability exists in some regions already, it is a cumbersome process involving downloading images from a digital camera to the laptop, attaching to an email, and sending the message. Currently, all center-to-vehicle connections with IRT vehicles are through private communications providers (CDPD and other cellular connections). Available wireless connection speeds may also hinder this effort.

3.5.1.2 Snow Management

In addition to the IRT Program, WSDOT is in Phase 2 of a "Smart Snowplow" or "Snow Management" Pilot Project. To test the feasibility and benefit of a Smart Snowplow system, WSDOT equipped several of their snowplows in North Central region with sensitive detection and data communications equipment, using the 800MHz radio network. Figure 24 illustrates an example of the Smart Snowplow concept, using a picture from the Minnesota Guidestar ITS Program.

Information collected from the snowplow includes real time vehicle location, using Differential Global Positioning System (DGPS), text-messaging capabilities between operator and dispatch, and specific sensors, including plow up/down, road and air temperature, etc. The first phase of the pilot project had mixed results. While the data collected was considered very valuable in some cases, there were problems with some of the devices sending a lot more data than was required. More importantly, it was found that the data sent over the 800MHz network had an adverse effect on voice communications, which was considered unacceptable to WSDOT. The communications equipment vendor (EF Johnson) hopes to demonstrate the proof of concept with better communications management in Phase 2.

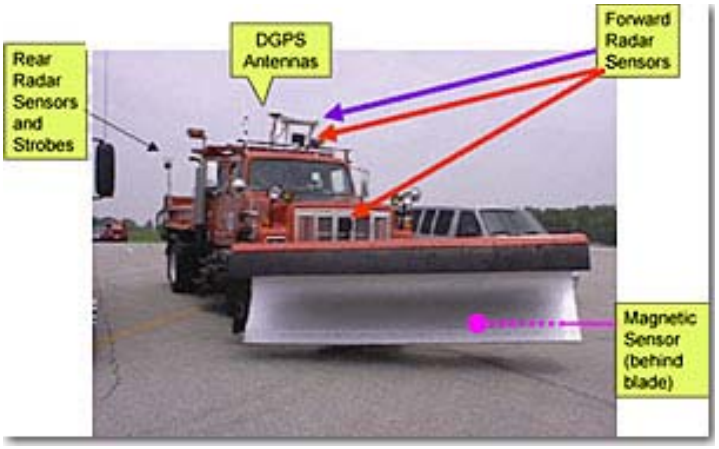


Figure 24: Example "Smart Snowplow"

3.5.1.3 Future Needs

WSDOT's IRT program is likely to continue to grow in terms of coverage, number of vehicles and data requirements. The ability to send back photos from an incident in real-time, while considered a future application, is likely to become a high-demand application once it becomes available. However, the private communications networks will not support the bandwidth that could be required, and more importantly, ATandT Wireless has already announced that they will be migrating away from CDPD services. While the service that replaces CDPD is likely to support higher bandwidth requirements, the cost may prove prohibitive across the IRT program.

WSDOT is closely tracking the success of Phase 2 of the Snow Management Pilot Project for a number of reasons. Most importantly, there is some interest in expanding the Automatic Vehicle Location (AVL) system to include more of the maintenance vehicles. Some see the ability of the dispatchers to know real-time vehicle locations as a valuable tool for more efficient maintenance of the statewide roadway network.

3.5.2 Center-to-Field Device

As discussed earlier, WSDOT's ability to communicate with field devices, most notably ITS devices such as CCTV cameras, Variable Message Signs, traffic data stations, HAR, etc, was one of the driving factors initiating the Light Lanes project. The collapse of the telecommunications market and the dissolution of the Light Lanes project was one of the key factors initiating this study.

WSDOT currently communicates with field devices in literally almost every imaginable communications medium available today, including:

- Fiber optics
- Microwave
- Licensed spread spectrum radio (including the 800MHz network)
- Unlicensed spread spectrum radio (including 802.11)
- Owned twisted pair
- Owned Coax (limited), and
- Dial-up services (T1, ISDN, DSL, 56k, etc.)

The ability of each region to make use of available resources to operate this varied network is quite remarkable. There are, however, some serious drawbacks to this diverse set of technologies. These include:

- **Maintenance**: Staff have to be trained in a number of different technologies to be able to maintain the network.

- **Standardization**: Lack of standardization leads to more difficult and costly design and often reduces quality of service.

- **Spare Parts**: Each different technology requires its own set of spare parts, which becomes costly to purchase, store and transfer to the site where needed. Alternatively, spare parts may not be held in stock by WSDOT, which leads to longer periods of down time.

- **Operational Costs**: Any dial-up services cost WSDOT monthly fees, which are often not well-documented and lead to misleading operational costs.

- **Device Utilization**: For remotely located CCTV cameras in particular, effective utilization of the device is often limited by the available bandwidth. For instance, if a slow speed dial-up connection is used to connect to a CCTV camera, snap shot, low quality images are usually all that can be collected. These images are often of less value to those utilizing them for incident or congestion verification and effectively diminish the value of the device itself.

3.5.2.1 Growth

The use and further deployment of ITS and other field devices appears likely to continue to grow for the foreseeable future. WSDOT has a number of ITS deployment projects (mostly funded) in various stages of planning, design and deployment, including the following:

Program Area	Project Title	County/Region
Safety	Critical Data Communications System Enhancement	Thurston/Olympia
	I-90 Truck/Wind Warning System Near Columbia River	Grant/North Central
Emergency Operations Projects	Remote Traffic Operations Center for Security and Emergency Applications	King/Northwest
Congestion Relief	Vancouver Area Smart Trek Operations and Communications Expansion and Traveler Information Integration	Clark/Southwest
	Tri-Cities Advanced Traffic Management System	Benton and Franklin/South Central
	Olympia Arterial Advanced Traffic Management System	Thurston/Olympia
	Seattle Incident and Operations Deployment	King/Northwest
	Lynnwood Regional ITS Operations System	Snohomish/Northwest
	Spokane Traffic Operations for Arterials	Spokane/Eastern
	Major Event Parking Advisory System	King/Northwest

Program Area	Project Title	County/Region
Traveler Information	Variable Speed Limit System on Stevens Pass, US-2	Chelan/North Central
	US-395 Columbia River Bridge Traffic Operations and Traveler Information System	Benton/South Central
	Central Washington Traveler Information Variable Message Sign (VMS)	Adams and Grant/North Central and Eastern
	I-82 Yakima Area Traveler Information System	Yakima/South Central
	I-5 Through Nisqually Valley – Ice Warning System	Thurston and Pierce/Olympia and NW
	SR14 Traveler Information Enhancements	Skamania/Southwest

Appendix B includes brief project descriptions of each of these projects, from the list of 2002 Proposed Washington State ITS Projects. As can be seen, every region has plans for additional field devices and associated communications requirements. While most are low speed connections (virtually all non-video applications only require low speed and low bandwidth communications) they still all require some sort of connection.

3.6 POLICY ISSUES

Some issues that have direct impact on WSDOT's communications needs, network, infrastructure and implementation options, are best defined as policy issues. Some examples include:

- **JOPS Discussion on Wireless Network**: As discussed above (Section 3.4), there is language in the Joint Operations Policy Statement referring specifically to the joint-owned wireless network, agreeing to "create a coordinated and integrated wireless transportation communications [network]." While both parties have accepted this language, the key will be to translate this agreement into specific actions, committees and deployable projects.

- **Wireless Task Force**: There is an existing inter-agency wireless task force that was created primarily to identify solutions for the interference problems discussed in detail in Section 3.4. This wireless task force is an advisory committee only, with no real authority and a very limited scope.

- **Limited Wireless Design Standardization/Review**: While there are a number of wireless communications projects connecting centers to field devices, they are generally designed in an ad-hoc manner, with no agency-wide design standards, and no centralized review process. There is some concern that as these projects continue to be deployed, they may cause interference problems with other systems and/or may not be deployed with the "bigger picture" in mind.

3.7 TELECOMMUNICATIONS MARKET REVIEW

The last section of "Findings" relates to a brief analysis of the telecommunications market in the State of Washington. Specifically, the goal of this task was to try to identify any opportunities to obtain fiber optic plant that a communications provider is willing to sell (or lease long term) along key sections of WSDOT infrastructure. The driving factor of performing this task was the logic that perhaps the collapse of the telecommunications market had opened up an opportunity to purchase existing fiber and/or conduit at low cost. This fiber could then potentially be used for either center-to-center or center-to-field applications, depending on route, location, etc.

3.7.1 Long-Haul Providers in Washington

Appendix B provides a high-level map of Long Haul telecommunications providers in the Northwest. This map was available on KMI Corporation's website at www.kmicorp.com [12]. KMI maintains and sells a number of state, national, and international fiber optic route maps. They have updated maps of the State of Washington for sale.

Figure 25 provides a matrix of long-haul telecommunications providers in the State of Washington, indicating which ones appear to own infrastructure along key WSDOT corridors. All the providers own infrastructure along I-5, either border-to-border (Oregon to British Columbia) or from Seattle-to-Portland.

[12] This map is to be used for informational purposes only. KMI does not verify 100% accuracy of this information.

Company	I-5 Corridor	Note	Seattle-Spokane	Seattle-Wenatchee	Seattle-Yakima	Other
360networks	**Yes**	**Border to Border, probably railroad**	no	no	no	
Enron	**Yes**	Seattle to Portland	no	no	no	
GST Telcom	**Yes**	Seattle to Portland	no	no	no	
Broadwind (IXC)	**Yes**	Seattle to Portland	**Yes**	no	no	
Qwest	**Yes**	Seattle to Portland (probably redundant route)	no	no	no	
PFNet	**Yes**	Seattle to Portland	no	no	no	
Frontier	**Yes**	Seattle to Portland (possible redundant route)	**Yes**	no	no	
MCI/Worldcom	**Yes**	**Border to Border, probably railroad**	**Yes (through Everett)**	**Yes (through Everett)**	no	**Everett-to-Wenatchee & Everett-to-Spokane (seems to bypass Spokane likely Hwy 2 both) & Wenatchee-to-Tri-Cities**
Touch America	**Yes**	**Border to Border, probably railroad**	**Yes (prob. Hwy 2)**	**Yes (prob. Hwy 2)**	no	
AT&T	**Yes**	**Border to Border, including specific Olympia to Tacoma Run**	**Yes (with redundancy)**	**Yes (prob. Hwy 2)**	**Yes**	**Redundant routes to Spokane, one appears as I-90 the other Hwy2**
Electric Lightwave	**Yes**	Seattle to Portland (probably redundant route)	**Yes**	no	no	**Portland-to-Yakima-to-Spokene**
Sprint	**Yes**	**Border to Border**	**Yes**	**Yes (prob. Hwy 2)**	no	
Williams	**Yes**	Seattle to Portland	no	no	**Yes**	**Portland-to-Yakima (loop to Seattle)**
Level3	**Yes**	**Border to Border**	no	no	**Yes**	
BPA/NoaNet	**Yes**	**Border to Border**	**Yes**	**Yes**	**Yes**	**Fiber to Tri-Cities & Olympic Penninsula, including Olympia-to-Port Angeles & Olympia-to-Aberdeen**

Figure 25: Long Haul Communications Providers in Washington

This matrix provide useful information in a couple of different scenarios:

1. If a communications provider DOES own infrastructure along a specific route (e.g., Highway 2) that WSDOT it interested in, WSDOT may contact them directly to investigate lease/buy options.

2. If a communications provider DOES NOT own infrastructure along a specific route (e.g., Highway 2) that WSDOT it interested in, WSDOT may contact them directly to see if they are interested in cost-sharing the construction or some other shared resource-type effort.

Figure 26 below provides a list of contacts for some of these communications providers.

Company	Contact Name	Ph. #
Electric Lightwave	Jennifer Bush	206-812-2296
360networks	Dick Wong	604-648-7818 office 604-307-6862 cell
NoaNet	Tom Villani	509-662-1244 office 509-668-0409
AT&T	Rick Leclair	425-943-3477
MCI/Worldcom	Mike Patterson	916-576-6721
Touch America	Commercial Customer C	(800) 590-1025
Sprint/Verizon	Ken Ng	(206) 254-5034
Enron	Company HQ	(713) 853-6161
Williams Comm (WiTel)		1.877.367.0767 (fiber) (866) 945-8351
Level3		(877) 253-8353

Figure 26: List of Telecommunications Provider Contacts

3.7.2 Fiber Optic Lease Options (360networks)

Many of the communications providers identified in Figure 25 were contacted as part of this task. The first question asked of each contact was whether the provider would consider either selling or entering into a long-term lease agreement with WSDOT for dark fiber or conduit along these key routes. At the time that this report was drafted, none of the providers would consider selling fiber or conduit and only 360networks indicated any interest in long-term lease options.

360networks owns a fiber backbone around the United States and Canada. This backbone runs parallel to the I-5 corridor from border-to-border, however, 360 has less available fiber in the segment from Everett north to the Canadian border than they do from Everett south to the Oregon

border. Appendix C[13] provides a route map of 360networks fiber route from border-to-border along the I-5 corridor.

Since 360networks had indicated interest in discussing a long-term lease agreement with WSDOT, they were asked to provide a budgetary estimate of what such a lease would entail. Appendix D provides a copy of the letter issued by 360networks in response to this request. To summarize the letter, 360 offered the following budgetary estimates:

1) Vancouver, WA to Seattle
Term: 20 Year IRU[14]
Fiber IRU Non-recurring Charge: $277,100 (2 fibers)
Route Maintenance Yearly Recurring Charge: $57,050 ($350 per route mile)

2) Seattle to Vancouver, BC
Term: 20 Year IRU
Fiber IRU Non-recurring Charge: $738,000 (2 fibers)
Route Maintenance Yearly Recurring Charge: $71,750 ($350 per route mile)

Other Services:
Splicing Non-recurring Charge: $5,000 per splice
Collocation: $750 per rack (Monthly Recurring Charge), $1,000 per Rack Installation Fee
Power: $15 per amp (Monthly Recurring Charge)

3.7.3 Long-Haul Circuit Charges

Another part of this task included requesting "circuit pricing" estimates from the telecommunications service providers for some of the key WSDOT Center-to-Center connections. Communications providers are often wary of presenting circuit-pricing information, unless they are in serious negotiations with a prospective client. Therefore, at the time that this report was drafted, only MCI/WorldCom had provided circuit-pricing information. This circuit-pricing information has been included as Appendix G, and is to be used for informational purposes only. This may help give budgetary estimates for approximate ongoing leased line charges for various circuit sizes.

Subsequent to the completion of this task, WSDOT continued negotiations with Qwest and NoaNet for several upgraded circuits (as discussed in Section 3.1.4). Because of WSDOT's bulk purchasing capabilities, the current state of the telecommunications industry, and WSDOT's successful negotiations, the monthly service fees negotiated with Qwest and NoaNet are substantially less than those estimates offered by MCI/WorldCom for even higher bandwidth. While the exact service fees are confidential, an estimate of $1500 per termination for dedicated bandwidth of 100Mbs has been verified as a close approximation.

[13] 360network noted the following "*this is not an engineering drawing, and as such the fiber route information may not be accurate or current. Please use it only as a high level reference.*"
[14] Indefeasible Right of Use

3.7.4 Monthly Lease vs. IRU

Comparing monthly lease cost to the long-term lease (IRU) costs (using 360networks as an example) are by no means, an "apples to apples" comparison. There are a number of issues that need to be taken into consideration, such as the Level of Service agreements that the communications providers are willing to provide, ownership and maintenance of network equipment, actual bandwidth available, annual increases in monthly rates, etc. However, a high-level look at cost comparison is worthy of some analysis.

Using the newly negotiated rates with Qwest and NoaNet in comparison with the 360networks dark fiber IRU (and including last mile construction costs to tie into 360networks fiber), there does not appear to be incentive to further analyze an IRU agreement at this time.

Example IRU vs. NoaNet Lease (all values approximate)

Vancouver to Seattle 20-year IRU through 360networks		
Fiber IRU non-recurring cost:		**$277,000**
Route maintenance cost:	$57,050 / year * 20 years	**$1,141,000**
Last Mile Cost:	$35/ft * 5 miles	**$925,000**
Equipment cost:		**$300,000**
	Total 20 year:	***$2,643,000***

Vancouver to Olympia 100Mbs NoaNet Estimate		
Initial install cost:		$**1500**
Monthly Fee:	$1,500 * 12 mo * 20 year	**$360,000**
Last Mile Cost:		**$0**
Equipment cost:		**$0**
	Total 20 year:	***$361,500***

3.7.5 NoaNet

Of all of the private telecommunications providers in the State of Washington, NoaNet (Northwest Open Access Network) is the most unique provider, and possibly the "best fit" for WSDOT's needs. As described on their website:

"*Northwest Open Access Network (NoaNet) is a nonprofit corporation that has licensed fiber optic cables from the Bonneville Power Administration (BPA) and other sources to create a carrier-class Data and TDM network for the Utilities and rural communities in the Pacific Northwest…*

The members of NoaNet are nonprofit, community-owned electric and water utilities. They use the NoaNet fiber optic system for utility purposes such as real-time metering, energy management, load control and networking among remote utility facilities. NoaNet provides excess capacity to others on a cost-based, nondiscriminatory basis. Communities are using the NoaNet system to interconnect schools, hospitals, judicial systems, libraries, and emergency services. The availability of fiber optics enables economically depressed communities to attract new businesses. NoaNet is also the rural community's on-ramp to the Internet, offering access through Tier 1 providers…

NoaNet's SONET-based, passive DWDM network was originally designed in 1999 and 2000 and is meant to carry advanced telecommunications and data services throughout rural Washington State. Our network parallels the BPA transmission system and uses fiber supplied by BPA, and other providers in areas where BPA doesn't have fiber."

The reasons that NoaNet may be extremely attractive to WSDOT are two-fold:

- **Pricing:** NoaNet's affiliation as a non-profit organization allow them to offer extremely competitive long-haul circuit pricing,

- **Location:** NoaNet's network creates a large ring around the State of Washington with many point-of-presence facilities located very close to WSDOT key sites.

Appendix E displays NoaNet's network map around the State of Washington, including fiber routes and point of presence facilities. Figure 27 is NoaNet's list of Point-of-Presence facilities in the State of Washington, including the physical address as well as Latitude and Longitude of each site.

NOANET POP LIST								
Site Name	Prop. Ownership	State	City	Zip Code	County	CLLI	NPA	NXX
Aberdeen	Collocation at Grays Harbor facility	Washington	Aberdeen	98520	Grays Harbor	ABE	360	532
Ashe	BPA	Washington	Richland	99352	Benton	ASH	509	942
Bell	BPA	Washington	Mead	98042	Spokane	BEL	509	242
Big Eddy	BPA	Oregon	The Dalles	97058	Wasco	BDY	541	320
Chehalis	BPA	Washington	Chehalis	98532	Lewis	CHS	360	740
Chief Joseph	BPA	Washington	Bridgeport	98813	Douglas	CHJ	509	686
Cle Ellum	Private	Washington	Cle Elum	98922	Kittitas	CLE	509	674
Columbia	BPA	Washington	Rock Island	98850	Douglas	COL	509	662
Covington	BPA	Washington	Kent	98042	King	COV	253	372
Creston	Private	Washington	North Creston	99122	Lincoln	CTN	509	636
Ellensburg	Private	Washington	Ellensburg	98926	Kittitas	EBG	509	933
Franklin	BPA	Washington	Pasco	99301	Franklin	FKN	509	542
Grand Coulee	BOR	Washington	Grand Coulee	99133	Grant	GRC	509	632
Happy Valley	BPA	Washington	Sequim	98382	Clallum	HVY	360	582
John Day	BPA	Oregon	Rufus	97050	Wasco	JND	541	739
Lexington	BPA	Washington	Longview	98632	Cowlitz	LEX	360	414
McNary	BPA	Oregon	Umatilla	97882	Umatilla	MCY	541	922
Midway	BPA	Washington			Benton	MID	509	
Moxee	BPA	Washington	Yakima	98901	Yakima	MOX	509	225
Olympia	BPA	Washington	Olympia	98502	Thurston	OLY	360	236
Pittock	Collocation	Oregon	Portland	97205	Multnomah	PIT	503	215
Ross	BPA	Washington	Vancouver	98663	Clark	ROS	360	546
Satsop	Collocation at Grays Harbor facility	Washington	Elma	98541	Grays Harbor	SAT	360	532
Sharkey	Private	Washington	Coulee City	99115	Douglas	SHK	509	632

Figure 27: NoaNet Point of Presence List for Washington